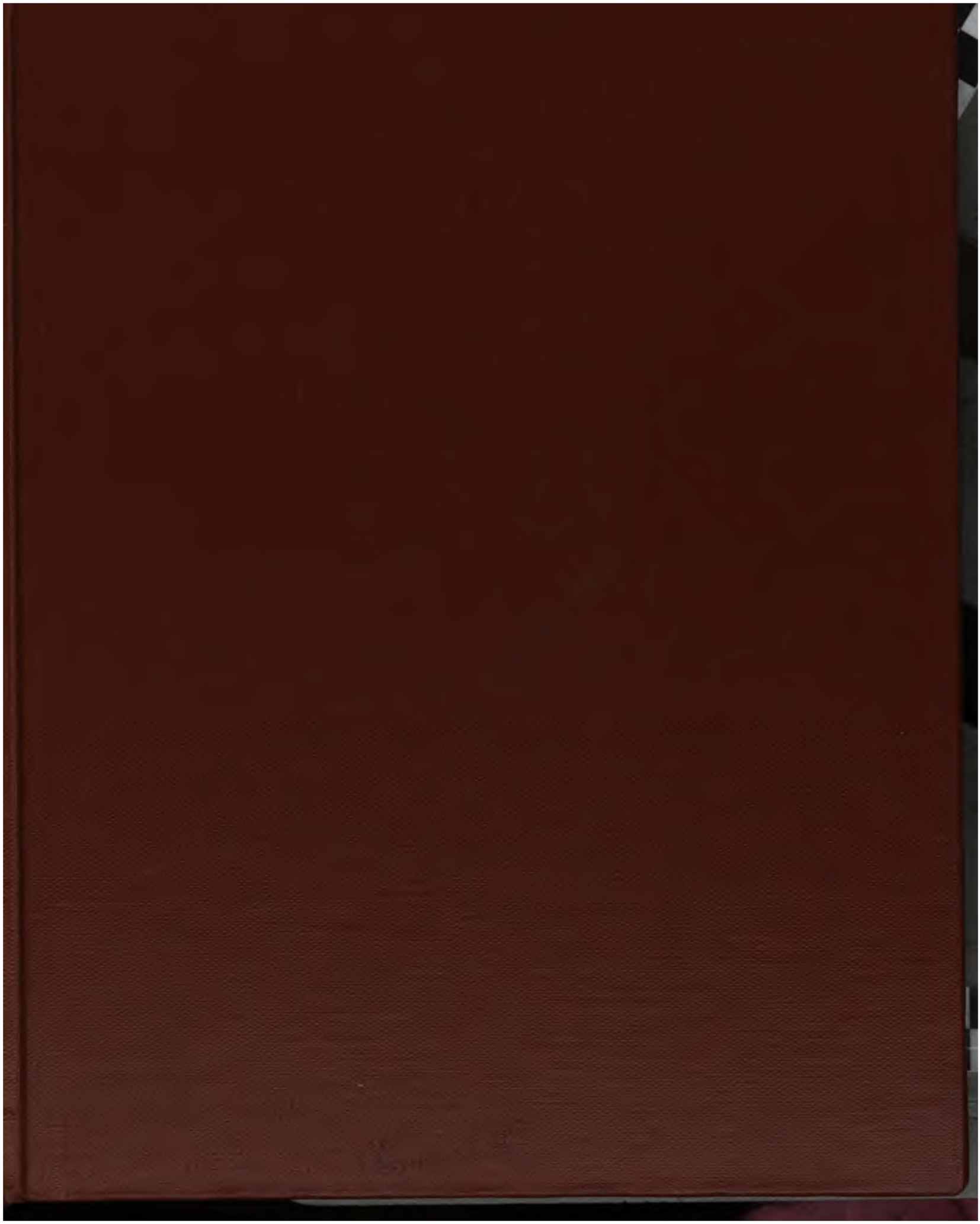

RESEARCH IN CHINA

IN THREE VOLUMES AND ATLAS

VOLUME ONE IN TWO PARTS

PART TWO

PETROGRAPHY AND ZOOLOGY

by

ELIOT BLACKWELDER

SYLLABARY OF CHINESE SOUNDS

by

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ERRATA.

Page 337, paragraph 5, line 5: for "epidote zoisite" read "epidote and zoisite."
Page 377, footnote: for "371" read "373."
Page 470, paragraph 5, line 1: in place of "this section" read "thin section."
Page 469, 4th line from bottom: in place of "Fig. 70" read "Plate LII, Fig. D."

SECTION IV

PETROGRAPHY

CHAPTER XVI.

ROCKS FROM NORTHERN AND CENTRAL CHINA.

By Eliot Blackwelder.

INTRODUCTION.

In the chapters on stratigraphy, the field relations of the rocks have been described and the prominent varieties have been briefly discussed. The more elaborate descriptions of rocks, depending upon the microscopical study of the specimens collected, are reserved for this portion of the report.

The rocks have been classified in the first instance by districts, secondly by geologic age, thirdly by mode of origin, and fourthly by petrographic character. In the detailed geological report, six districts were distinguished for convenience in description. In the present work eleven will be recognized, some of which correspond to those mentioned above, while others are either new or have been formed by subdivision of the old districts. They are named as follows: Khin-gan district, Liau-tung district, Liau-si district, Peking basin, western Shan-tung, eastern Shan-tung, western Chï-li, Wu-t'ai district, Ts'in-ling district, Han river district, and Yang-tzï gorge district. Within each of these divisions there is a general similarity among the rocks, as contrasted with the assemblages which characterize other areas. It is not intended, however, to convey the idea that they represent definite petrographic provinces; the material at our command is, in most cases, entirely insufficient to attempt a classification of that nature which could stand the test of more detailed work in the future. The sedimentary and metamorphic rocks are here classified according to the system used by Van Hise,* while the igneous varieties are named and arranged in general accordance with the usage of recent petrographers.

In studying the rocks from China, the writer has had the privilege of consulting Professor J. P. Iddings, of the University of Chicago, and Professors C. K. Leith, W. H. Hobbs, and W. O. Hotchkiss, of the University of Wisconsin. The advice and criticism they have freely given add largely to the value of the work.

* Van Hise: A Treatise on Metamorphism, U. S. Geol. Survey, Monograph XLVII.

KHIN-GAN DISTRICT.

While crossing the Khin-gan range, in northwestern Manchuria, on the Chinese-Eastern (Trans-Siberian) railroad, we observed, in a very casual way, something of the geological formations there exposed. Inasmuch as the party did not stop to undertake field-work on this part of the journey, the Khin-gan district, so called, will be understood to include only that portion of the range which can be seen directly from the railroad.

Rocks of Igneous Origin.

The rocks of the Khin-gan district appear to be very largely igneous. In addition to the granite, which is described below, igneous rocks in considerable variety were observed in the gravel which covers the valley-floor near Barim. Among these were black quartz porphyry, purplish and flesh-colored hornblende porphyries, feldspar porphyry, and gray hornblende granite. Nothing was learned regarding the occurrence and relationships of these rocks, but it is evident that all of them outcrop in the valleys of this stream or its tributaries.

Gray biotite granite, No. 1.—This granite forms the axial portion of the Khin-gan range, at the point where it is crossed by the Chinese-Eastern railroad. Although limestone and other rocks of sedimentary origin occur at no great distance to the westward, it was not practicable to ascertain the relation which the granite bears to these and to other igneous rocks of the region. Specimen taken on the east side of the Khin-gan pass 400 feet, 120 meters, above the tunnel.

The rock is rather coarse-grained and shows only a trace of gneissic banding. The more abundant minerals are quartz, microcline, and plagioclase, with lesser amounts of orthoclase and biotite. Among the accessory minerals which occur in small quantity are hornblende, titanite, magnetite, apatite, tourmaline, and zircon.

The quartzes are pale smoky in color with a faint tinge of violet. They include an abundance of hair-like crystals, or trichites, probably rutile.

Microcline, the most abundant feldspar, occurs in rather large white crystals, which have suffered but little alteration. Incipient decay into kaolinic material develops first along certain of the twinning lamellæ, giving the feldspar a streaky appearance in ordinary light. Although the flesh-colored orthoclase occurs in large crystals, it is the least abundant of the feldspars. Like the microcline, it is comparatively little altered chemically. The plagioclase is a sodic feldspar which probably has the composition of oligoclase. That it began to crystallize earlier than the other feldspars is indicated by the fact that it frequently occurs in idiomorphic crystals, often twinned according to the Carlsbad law. In contrast to the potash feldspars, these plagioclases have suffered extensive alteration into saussurite.

Hornblende occurs only rarely in the Khin-gan granite. It is olive-green, with the pleochroism ranging from pale yellowish-green to dark olive. Most of the crystals have been altered in the upper zone, the process resulting in the formation of chlorite and epidote.

Biotite is the only abundant ferro-magnesian mineral present. It occurs in irregular olive-brown plates, which are partially altered to chlorite, epidote, and magnetite. The chlorite develops along the edges of the flakes and grows inward in streaks along the cleavage, until, in some cases, it has formed pseudomorphs after the biotite.

Of the less common constituents, titanite appears in the familiar wedge-shaped crystals and irregular grains, usually in association with biotite. Magnetite, as a primary constituent, forms angular grains, sparsely distributed, and together with ferric oxides is a secondary product of the alteration of the ferro-magnesian minerals. Small prisms of apatite, zircon, and a few of tourmaline, are scattered through the rock; as usual, they were among the first minerals to crystallize.

Evidences of deformation are not prominent in this granite. The effect of permanent strain is seen in the undulatory extinction of the quartzes. The parallel streaks of inclusions, which traverse many of the crystals of both quartz and feldspar irrespective of crystal boundaries, may also be due to dynamic metamorphism.*

LIAU-TUNG DISTRICT.

This district includes the peninsula of Liau-tung in southern Manchuria. Geologic studies by the writer were limited to the western border of this mountainous region. The rocks observed belong to several distinct systems: (*a*) the T'ai-shan gneissic complex (Archean), (*b*) the Ta-ku-shan system of schists, quartzite and marble (Algonkian), (*c*) the Sinian system (Cambro-Ordovician), and igneous dikes.

TA-KU-SHAN SYSTEM.

Rocks of Sedimentary Origin.

Crumpled sideritic slate, No. 61.—This slate is a phase of the dark-red, gray, and black slates which lie beneath marble and quartzite at Ta-shï-kiau station on the railroad to Port Arthur. The strata are only moderately metamorphosed. The most conspicuous features of the rock are the red-brown rhombs of iron ore which are abundantly interspersed through the gray silky slate. The cleavage planes are crumpled and ribbed in parallel lines. On closer examination the mass is seen to consist of finely divided quartz, kaolin, sericite, etc.—a typical clay slate.

* Streaks of similar inclusions in quartz-schist from the Black Hills are regarded by Van Hise as metamorphic developments. (G. S. A. Bull. 1, p. 217.)

The schistose arrangement of the micaceous minerals is prominent. The iron ore is hematite, now largely altered to limonite, but the perfect rhombic forms of the bodies indicate that they are pseudomorphs after siderite which has been subjected to weathering. These rhombs of quondam siderite lie with their longer axes parallel to the schistose structure and usually lie in "eye-spots" formed by the divergence of the minute shear-zones as they encounter the rhombic crystals. The matrix is least disturbed in the angles of these "augen" and most sheared and sliced along their flanks where stresses have been most intense.

The original rock appears to have been a ferruginous clay. The rhombs of siderite may represent initial deposition, but probably they grew in the clay by segregation of the iron-carbonate content. Under conditions of heavy pressure in a deeper zone the mass was somewhat deformed. Schistosity began to develop, but the process did not progress far enough to distort the siderite. Subsequently hematite replaced the siderite and it is now in turn weathered and largely altered to the hydrous oxide.

SINIAN SYSTEM.

Rocks of Sedimentary Origin.

Psephites.

Quartzite conglomerate, No. 62.—A moderately coarse conglomerate from the Yung-ning formation (Lower Cambrian?) 2 miles, 3 kilometers, north of Fu-chóu. It is not known to be a basal conglomerate.

The pebbles are well-rounded pieces of resistant rocks, such as vein-quartz, gray, black, and banded chert, and brown iron ore. They are firmly embedded in a coarse gray sandstone, the grains of which are cemented with quartz.

Psammites.

Ferruginous arkose, No. 65.—A characteristic example of the harder strata in the Yung-ning formation. Specimen taken 3 miles, 5 kilometers, northeast of Ch'au-kia-tién, between Fu-chóu and Siung-yué-ch'öng.

The rock is a hard, coarse-grained arkose or grit of red-brown color. The red hue is imparted by abundant red feldspars.

Quartz and feldspar together constitute the largest part of the mass. In addition there are abundant grains of magnetite and hematite. The grains are irregular or subangular, but do not show the rounded forms of well-worn sand. The cement, which binds the grains into a hard rock, is argillaceous; it consists of the debris of decayed feldspars and comminuted quartz. Oxides of iron stain the cement yellow and brown in certain areas, and chlorite locally imparts a green tinge. Evidence of deformation is very slight.

Rocks of Igneous Origin.

Rhyolite Porphyries.

Buff rhyolite, No. 64.—Our specimen is a badly decayed piece of one of the numerous small dikes which invade the Yung-ning sandstone (Cambrian?) between Ch'au-kia-tién and Li-kuan-ts'un. Its associates are gray, greenish, and black andesitic and basaltic porphyries of notable variety.

The pinkish buff ground-mass of the rock was feldspathic, but in this specimen is completely decayed. The numerous phenocrysts, which are of smoky quartz and buff feldspar, are remarkable for their perfect crystal forms. Many of the quartzes are short prisms with complete pyramidal terminations.

The rock has suffered no changes except those which characterize the belt of weathering. The former existence of flow structure is suggested by parallel dark and light bands which cross the specimen.

Buff hornblende rhyolite, No. 66.—The small dike from which the specimen was taken cuts dark porphyry and an included mass of marble 4 miles, 6.5 kilometers, south of Siung-yué-ch'öng. The marble is Algonkian, but the dike is probably of the same age as the last, *i. e.*, Post-Cambrian.

This variety differs from the last chiefly in containing many small phenocrysts of green hornblende. The decayed feldspathic ground-mass and the idiomorphic crystals of quartz and feldspar are similar in the two cases.

Basalts.

Hornblende basalt, No. 63.—The specimen came from a small dike in the Yung-ning sandstone less than 3 miles, 5 kilometers, north of Fu-chóu.

The rock is dark gray with indistinct greenish blotches. There are no phenocrysts and the texture is densely aphanitic.

The microscope reveals a matted network of long prisms of feldspar and hornblende set in a feldspathic paste. The feldspars are zonally built, but the average composition is near labradorite. The brown amphibole is scarcely pleochroic and may be largely decayed. The identification of it rests largely upon the occurrence of numerous rhombic basal sections. Abundant grains of magnetite are scattered through the rock.

Calcite is present in large quantity as a secondary mineral. It occurs in part irregularly and in part as a replacement of small olivine phenocrysts. The former presence of the olivine is indicated by the characteristic forms of the calcite pseudomorphs. Chalcedony locally forms a part of these calcite bodies.

LIAU-SI DISTRICT.

The hills and irregular low mountains which flank the broad plain of the Liau-ho on the west are often grouped under the name Liau-si in contrast to those on the east (Liau-tung). Our observations in this region were confined to the cursory examination possible in a journey by railroad from Yin-k'ou to Tientsin. From von Richthofen's report it is evident that the rocks are in general like those on the east.

ALGONKIAN.

Rocks of Sedimentary Origin.

Psammites.

White schistose quartzite, No. 60.—Pieces of this quartzite are used as railroad ballast at Kou-p'an-tzï junction. From Mr. Leitch, the English inspector of that portion of the railroad, I learned that the rock is exposed in an isolated hill southeast of Kau-shan-tzï, near Kuang-ning-hién. At that point it is associated with the gray marble which has been utilized in making the platform at Kou-p'an-tzi. These rocks bear a general resemblance to the Ta-ku-shan (Algonkian) series of Liau-tung.

A grayish-white coarse-grained quartzite in which there are obvious traces of schistose structure. The grains are mainly clear quartz with a few white feldspars now extensively altered to kaolin. The original cement between the grains has been obliterated in the metamorphic process to which the rock has been subjected.

Evidences of deformation are conspicuous when the rock is examined in thin section. All elongate grains lie parallel to the planes of cleavage. Many have been severely strained and even fractured. The sand-grains are now embedded in a schistose matrix of granular quartz, with flakes of kaolin and sericite. The intimate relation of this material to the ragged edges of the sand-grains indicates that it is largely the result of heavy stresses which have granulated and pulverized the original cement and parts of the adjacent grains. Under the same conditions the micaceous flakes have been developed in parallel orientation. A notable portion of the rock has thus been reduced to minute fragments.

Rocks of Igneous Origin.

Granites.

Gray biotite granite, No. 58.—North of the railroad station of Shï-san-ch'an this granite is quarried from a rugged hill at the edge of the alluvial plain. Its relations to the other rocks are not known, but it agrees well with descriptions of von Richthofen's "Korea granite," which is of Algonkian age.

The granite possesses a speckled appearance because smoky quartz and black biotite are embedded in white feldspars. The quartz and feldspar together appear to form more than 80 per cent of the mass. The feldspars are orthoclase with a subordinate amount of oligoclase. Both are slightly altered. In addition to the olive-brown biotite there are a few grains of titaniferous magnetite bordered in some cases by sphene.

The granite has not been greatly strained. Undulatory extinction of the crystals and occasional loci of granulation are the only evident results.

Flesh-colored aplite, No. 59.—The rock is used as railroad ballast near Shï-san-ch'an and is obtained from a quarry southwest of the granite.

A dense lithoidal rock of light color minutely speckled with black. It consists of finely granular quartz and alkali feldspar intimately mingled and of uniform texture. The black specks noted in the large prove to be minute bits of iron oxides. There are no phenocrysts.

The mass shows no marks of alteration and it is believed to be an unaltered igneous rock of highly siliceous composition.

PEKING BASIN.

This area includes the embayment of fluvial plain in which Peking is situated. No systematic petrological work was attempted in this area, and the rocks of the region are represented in our collection by only one specimen.

Rocks of Igneous Origin.

Greenish aporhyolite, No. 156.—The aporhyolite occurs in an isolated ridge surrounded by alluvium about 4 miles, 6.5 kilometers, southwest of Chang-p'ing-chóu, or 20 miles, 32 kilometers, northwest of Peking itself. Its relations were not observed, but judging from the reports of earlier explorers,* this is one of the volcanic rocks which are associated with the post-Sinian sediments north and west of Peking.

A fresh-looking greenish lava with a dense stony ground-mass, through which are scattered abundant phenocrysts of glassy and smoky quartz, together with reddish feldspar and biotite. A few of the feldspar crystals attain a breadth of nearly ½ inch, but the majority are much smaller. In the hand-specimen one fails to see any suggestion of banding, perlitic parting, or other textural peculiarities which are common among the rhyolites.

In the thin section the stony ground-mass appears cloudy grayish-brown in ordinary light. Between crossed nicols it behaves as an isotropic

*Von Richthofen mentions the occurrence of volcanic flows and agglomerate near Chang-p'ing-chou, but describes the rock as carmine-red and containing white feldspar phenocrysts. (China, vol. II, pp. 316–321.) Pumpelly appears not to have visited this locality, but he described "greenish felsitic porphyries" which he observed at Ching-t'ai (which is not far to the west of Chang-p'ing-chou) in the form of dikes cutting Sinian limestones. (Smithsonian Contributions to Knowledge, vol. XV, p. 13.)

medium, and as it has a low index of refraction, the natural inference is that the material is rock-glass. Under a high-power objective, however, the ground-mass is seen to be more or less granular, the individual grains being obviously birefringent. One of the minerals appears to be quartz.

This matrix shows, though somewhat indistinctly, flowage and even microperlitic structures. Although the perlitic fracturing is far from being prominent, it can be seen in the thin sections at several points. Grouped in certain areas, which are more obviously crystalline than others, there are a few rounded bodies which appear to be altered spherulites. They are now opaque white in color and probably represent altered feldspar microlites arranged in rosettes.

The flowage of the viscous lava, previous to its solidification, is shown in two ways. In the first place, some of the phenocrysts have been fractured and the broken pieces dragged apart by the matrix. Most of the micas have been sharply bent and dislocated, and in some cases there are planes of movement in the adjacent ground-mass, corresponding to the fractures in the biotite. There are also winding streaks, like microscopic shear-zones, which bend out around such phenocrysts as they encounter, but are otherwise approximately parallel. In some cases the crystals seem to have been rotated between the unequally gliding layers

The phenocrysts consist principally of quartz and orthoclase, with albite, biotite, and a few accessory minerals in smaller grains. Crystal faces are frequently well developed in all of these. The quartz is clear and almost free from inclusions. The orthoclase is also clear and is so fresh that it is often difficult to distinguish it from the quartz. Some of the crystals, however, exhibit cleavage cracks along which the processes of weathering have begun to change the feldspar into its usual decomposition products. The orthoclase crystals are frequently Carlsbad twins. The striated albite occurs, for the most part, in smaller crystals than the orthoclase and has progressed farther in decay. The alteration is most prominent around the edges, and it is therefore common for the albite crystals to possess narrow cloudy borders. Biotite is quite infrequent, but occurs in irregular plates. Magnetite occurs in medium-sized crystals which are partly altered to ferric oxides. Zircon and brown tourmaline are also present.

Associated with the phenocrysts there are small angular bits of a material much like the ground-mass. They have curved edges and are often elongated and stringy, like fragments of pumice. Certain small bodies of chalcedony apparently fill cavities which existed in the rock after it had finally hardened. The slide also reveals certain foreign bodies of irregular shape embedded in the mass. One of these is a bit of flint, and another appears to be glassy basalt containing numerous little laths

of plagioclase and bits of magnetite. Such fragments may have been incorporated in the lava in the process of extrusion.

It is evident that this porphyry formerly had a glassy ground-mass, but devitrification has set in and the whole mass is now crystalline, although a high power of the microscope is required to reveal the fact. The structures which have just been described indicate that it was, in all probability, a superficial lava flow. Since its extrusion it has been subjected to no metamorphic process other than those which are characteristic of the belt of weathering.

WESTERN SHAN-TUNG.

Roughly speaking, this district includes the western mountainous portion of the province centering about the holy mountain, T'ai-shan. It extends west and north to the plain of the Yellow river. It is separated from the mountainous district of eastern Shan-tung by a belt of lowlands in which the surface rocks are largely weak strata of Carboniferous and later age. Within the district the rock formations range from the oldest Pre-Cambrian to the early Mesozoic (?), and they consist of igneous, metamorphic, and sedimentary rocks.

T'AI-SHAN COMPLEX.

The following descriptions represent most of the prominent varieties of igneous and metamorphic rocks which occur in the basal Pre-Cambrian system.* The slopes of the T'ai-shan itself offer an excellent opportunity for the collection of fresh material and for the study of the mutual relationships of the rocks in the field. Other valuable localities may be found in almost any part of the district where the ancient rocks are exposed.

Rocks of Doubtful Origin.

Gneisses and Schists.

The oldest rocks which have been discriminated in the Archean complex are certain gneisses and schists. They have been so severely metamorphosed that their origin is no longer demonstrable by present methods. The gneisses are suggestive, however, of altered granites, and there is a significant lack of the types of schists which commonly develop from sedimentary rocks. We have not observed any which might not be derived from igneous material.

Gray biotite gneiss, No. 30.—This is one of the coarser phases of the gray gneiss which forms a large part of the Pre-Cambrian complex. It is believed to be a deformed granite. It is not possible at present to define its relation to the other phases of the gneiss described in succeeding

*Von Richthofen mentions and briefly describes the more prominent members of the T'ai-shan system (China, vol. II, pp. 195–220).

pages. Good exposures are to be seen along the stairway up the T'ai-shan at altitudes between 4,000 and 5,000 feet, 1,200 and 1,500 meters, above sea-level. Specimen 30 was taken there at 4,200 feet, 1,260 meters, elevation.

A medium-grained black-and-white gneiss with wavy banding. White lenticular spots or "augen" are developed on a small scale, but the feature is hardly prominent enough to justify the application of the term "augen-gneiss" to the rock. The foliation planes are dark with leaves of brown and black mica, together with a subordinate amount of hornblende. The quartzes and feldspars are for the most part glassy or white in color, occasionally with flesh-colored tints.

The preponderant minerals in this gneiss are quartz, plagioclase, orthoclase, microcline, and biotite; with hornblende, epidote, titanite, magnetite, and apatite as accessories.

The quartzes all show effects of mechanical strain. In most of the crystals strain-shadows are prominent, and many contain streaks of inclusions. Some of them have been fractured and exhibit incipient granulation at some of the points of contact with other crystals.

Among the feldspars a sodic plagioclase which occurs in large crystals, particularly in the lenticular "augen," seems to be an original constituent of the rock. In contrast to the fresh crystals of the potassic varieties associated with it, this feldspar is almost always considerably altered to saussurite and mica. The orthoclase also seems to be, for the most part, an original mineral, but certain clear grains are almost surely of a secondary nature. It is frequently cracked and may show granulation at some points, as does the quartz. The microcline is apparently confined to the areas of quartz-and-feldspar mosaic which are obviously the result of recrystallization; the feldspar, in these cases, occurs in small crystals which are perfectly fresh.

The dark bands in the gneiss are composed, for the most part, of interlaced leaves of biotite, and green hornblende. Their freshness, their parallel arrangement, and their segregation apart from the lighter zones of quartz and feldspar, indicate that both of these darker minerals have been developed during the process of metamorphism. The biotite is dull brown in color and is almost unaltered. The hornblendes are deep green, pleochroic, and frequently occur in twinned crystals. A certain amount of mechanical deformation seems to have taken place since the hornblende was formed, for some of the crystals have been bent or fractured.

Alterations of the hornblende to biotite and grains of epidote are not infrequent—a process which is known to be characteristic of the zone of

anamorphism.* Titanite, in the usual wedge-shaped crystals, and irregular magnetites are frequently associated with the seams of biotite and hornblende. Idiomorphic prisms of apatite, and, rarely also, of zircon, are distributed through the rock.

Biotitic hornblende gneiss, No. 29.—This is a local phase of the gray gneiss, which is intermediate between Nos. 28 and 30, though most resembling the latter. It is finer grained than No. 30, and biotite is not as important a mineral as in that variety. Locality: T'ai-shan, a few meters above the rock last described (30).

This differs from No. 30 chiefly in its finer texture and larger proportion of hornblende. The dark and light bands are parallel and not wavy.

The essential minerals in this gneiss are orthoclase, albite, quartz, and hornblende, while the less common constituents are zircon, pyrite, titanite, rutile, ilmenite, biotite, zoisite, epidote, and allanite. The crystals are arranged in layers, some of which are rich in hornblende, while others contain little besides quartz and feldspar. Taking this into account and noting the general absence of strain-shadows, shear-zones, etc., we must conclude that the rock has undergone complete recrystallization. Since this variety is much like No. 30 on the one hand and No. 28 on the other, it will suffice to point out only one or two features which are of especial interest.

Where lime-soda feldspars are present, one of the commonest alteration products is saussurite, a mixture of zoisite with various other minerals. Here we have abundant little prisms of zoisite inclosed in alkali feldspars and often associated with epidote. Manifestly, they could not be derived alone from minerals so poor in calcium. It is noteworthy in this case that the little crystals are most numerous in proximity to hornblende crystals and particularly to those in which alteration has evidently begun. Probably the hornblende has furnished a part of the material for the zoisite and epidote. The alteration of hornblende to biotite is well shown in this slide. The mica penetrates the hornblende like a parasitic growth and is surrounded by a bleached area in which the amphibole is colorless. Simultaneously with the biotite epidote is formed, and later the biotite may be changed in part or entirely to chlorite.

Two of the rarer minerals deserve mention in this connection. In most of the Chinese rocks which contain it, allanite is inclosed in epidote. Here, however, it occurs in zoisite. The titanite is brownish in color and in many cases it has inclusions of a deep brown color, which appear to be rutile.

* Van Hise: A Treatise on Metamorphism, p. 288.

Dark hornblende gneiss, No. 28.—A more basic phase of the ancient gneisses than either Nos. 29 or 30. The rock is frequently schistose and grades off into hornblende schists such as No. 27. Specimen collected at an elevation of 4,300 feet, 1,300 meters, near the granite stairway up the T'ai-shan. This is a dark, greenish-gray, indistinctly banded rock, the most prominent component of which is a blackish hornblende disposed not only in thin layers but in small lenticular knots parallel to the banding.

The rock consists of feldspar, hornblende, and quartz, with lesser amounts of biotite, titanite, and pyrite. Hematite, epidote, and zoisite are present as alteration products. Judging from its composition the rock was originally a moderately basic igneous rock, but its constituents have evidently been completely rearranged, old compounds having been broken up and new ones formed. The minerals now present are probably all secondary developments or even later alterations of them.

The quartz, albite, and orthoclase appear in medium-sized allotriomorphic grains. In our specimen the feldspars are considerably altered to saussurite and micas. The light-green hornblendes, which are abundant in clusters or in scattered irregular crystals, have probably been constructed in large measure out of the original amphibole or pyroxene. It is rare to find these hornblendes in well-shaped crystals; they are usually closely packed and mutually interlaced in flat lens-shaped groups. Although subsequent decomposition of the hornblendes has not progressed very far, it has in some cases produced aggregates of epidote, hematite, and quartz. The subordinate amount of biotite present seems also to be a later development of the hornblende. It invades the latter along edges and often grades into the hornblende without any distinct boundary. This relation can be more clearly discerned in No. 27.

A few grains of pyrite and magnetite are probably primary crystals. The former are generally surrounded by partial pseudomorphs of hematite, and other crystals of this iron oxide may also have been derived from the alteration of the pyrite.

Biotitic hornblende schist, No. 27.—Apparently a basic phase of the hornblende gneisses just described. Specimen taken near No. 30 at 4,200 feet, 1,260 meters, elevation on the south slope of the T'ai-shan.

This rock is, in most respects, similar to the last described (No. 28), but in this case the schistosity is well developed. The cleavage faces exhibit not only the dark hornblendes but also a considerable amount of brown mica. The hornblendes and micas lie interlaced in layers which have a very marked parallelism. From the fact that the biotites penetrate and feather into the hornblendes it is evident that they are later and have been derived in part at least from the latter.

Both of these minerals have also undergone more recent, although slight, katamorphic changes which have resulted in the production of granules of epidote, quartz, etc. Other changes, characteristic of this zone, appear in the alteration of the ilmenite to leucoxene, and of the magnetite to pyrite and hematite. In this rock one also finds small grains of rutile, many of which, like the ilmenite, have narrow borders of titanite, as described by Hobbs* and others. Allanite inclosed in epidote is not uncommon here.

Biotitic hornblende schist, No. 21.—This mica schist appears to be one of the oldest constituents of the basal complex. It is so intimately associated with the gray gneisses that it was not found practicable to ascertain the relationship between the two, but on several occasions lenticular bodies of the schist were found included in large masses of the gray gneisses, as if they were bits of the older rock torn off by a rising granitic magma. Specimen taken from such an inclusion in the gneiss at the mouth of the ravine about 1 mile, 1.6 kilometers, west of Ch'ang-hia.

A rather imperfectly schistose, dark, reddish-brown rock in which dark micas cover the cleavage faces. It differs from Nos. 27 and 28, chiefly in having a larger proportion of quartz, feldspar, and biotite, and from all the preceding members of the complex in the red color of its feldspars. The hornblendes, and especially the micas, are arranged in streaks with the axes of the individual crystals roughly parallel. Most of the orthoclase and quartz occurs in small irregular grains, and even among these the more elongated crystals lie with their axes parallel to the schistosity. There are, however, a few larger feldspars which are situated in "augen" around which the micas and hornblendes bend in the same manner as in the conglomeratic schists. The corners of these "augen" are filled with granulated feldspars. It is believed that these are primary feldspars which have been only partially reduced during mechanical deformation of the original rock. Since the deformation all of the feldspars have undergone weathering, and they are now clouded with gray and reddish decomposition products.

On the whole, biotite is rather more prominent in this rock than hornblende. It is probably a secondary development derived in part from the alteration of the hornblende; this would result from a further advance of the alteration noted in Nos. 27 and 28. The mica flakes have begun to lose color along the cleavage cracks and in many cases are partially altered to chlorite and epidote. The same minerals are likewise produced by changes in the hornblende.

Several varieties of the iron ores occur in abundant small grains. Magnetite is probably the most common and is distinguished by its charac-

* Wis. Acad. of Sci. Transactions, vol. VIII, pp. 155–159.

teristic forms. Ilmenite is frequently surrounded by narrow fringes of titanite and the latter is also distributed in unusual profusion throughout the rock in the form of irregular grains. Pyrite grains included in hematite pseudomorphs are also not uncommon.

Other accessories, such as apatite, rutile, and greenish tourmaline, occur rather abundantly in very small crystals. A few of the epidotes also inclose allanite.

Gray biotite gneiss, No. 22.—This is one of the common types of gray gneiss in Shan-tung. Specimen collected near the village of Ch'ang-hia, associated with No. 21.

This is a rather dull-gray gneiss of fine texture and blended colors. Although the banding is distinct, the laminæ are not well defined, and the individual layers can not be traced for any considerable distance. In this phase of the gneiss there is no development of the "augen."

The predominant minerals disclosed by the microscope are quartz, orthoclase, and biotite. With these are associated, in subordinate quantity, plagioclase, magnetite, titanite, apatite, epidote, rutile, and zircon. The larger quartz crystals show undulatory extinction strongly, and are somewhat granulated along their edges in certain places. The orthoclase shows similar features and, in addition, is frequently crossed by zigzag fractures. This feldspar is also partly changed to brown decomposition products, particularly along the principal cleavage planes and near the centers of the crystals. The plagioclase always extinguishes at low angles, indicating that it is probably albite or oligoclase. It has suffered less alteration than the potassic feldspar.

The greenish plates of biotite are arranged in roughly parallel seams. They are not much altered, but wherever they are decayed epidote is produced through the well-known reaction which is common in the belt of weathering.*

Fine-grained epidote gneiss, No. 34.—A rather unusual phase of the T'ai-shan gneisses. Collected near the great stairway on the T'ai-shan, at an elevation of 4,500 feet, 1,350 meters, above sea-level.

The gneiss is light-gray with a tinge of green, and in spite of the very fine texture, the arrangement of the darker and lighter minerals in bands is quite distinct. The quartz and feldspars are almost colorless, the greenish hue being due to the presence of epidote and hornblende.

Quartz, orthoclase, and epidote are the dominant minerals. A sodic feldspar, zoisite, biotite, and hornblende are less abundant; and there is a scattering representation of the usual accessory minerals, such as titanite, hematite and magnetite, zircon and apatite.

* Van Hise: A Treatise on Metamorphism, p. 340.

The quartz appears in fresh interlocking crystals, which are but little strained, and evidently are the result of the recrystallization of the original quartz.

The striated feldspars are subordinate to orthoclase and have a composition ranging from albite to oligoclase. The majority of the feldspars of both kinds are thickly set with inclusions which are the products of weathering. Kaolin and muscovite are the commonest of these products, but zoisite and epidote are scattered rather abundantly through the feldspars as if the latter had contributed largely to the formation of them. Associated with interlocking grains of quartz there are also small fresh crystals of orthoclase and microcline, which have doubtless developed from the recrystallization of altered feldspars.

The hornblende is bluish-green, varying in its pleochroism to pale yellowish-green. The crystals are all small and irregular, and are segregated to some extent in parallel bands in company with epidote. Most of them have been extensively altered into epidote, zoisite, and quartz. The brown mica is decidedly rare and occurs as irregular scales. The color is much too light for biotite, the feeble pleochroism ranging from colorless to pale russet-brown. It is not improbable that we have here the lithia mica, lithionite.

The minerals now visible are probably all secondary in origin. Most of the quartz seems to have been rearranged in bands, and the parallelism among the hornblendes indicates that they are the results of metamorphic processes acting upon still older ferro-magnesian minerals. The subsequent change of the greater part of the hornblende into epidote, etc., gives the rock its present specific character.

Rocks of Igneous Origin.

Granites.

The T'ai-shan complex includes several varieties of granites. In the Ch'ang-hia district a reddish rock is prevalent, but in the T'ai-shan itself several different granites are associated. Some of them are found intruded into the gneisses and hornblende schists, and it is highly probable that they are all younger than those more severely metamorphosed rocks.

Red gneissoid granite, No. 20.—The red granites are intrusive in the more ancient gray gneisses and hornblende schists of the T'ai-shan complex. In volume they form a large proportion of the Pre-Cambrian system and they are exposed extensively in many places. Specimen No. 20, collected near the head of the ravine about 2 miles, 3 kilometers, due west of the village of Ch'ang-hia.

A light reddish-brown granite in which gneissic banding is scarcely discernible. The texture of the mass is rather fine.

Much the larger part of this rock is made up of quartz and the alkali feldspars, orthoclase, microcline, and albite. The darker colored minerals are for the most part biotite and secondary epidote. As accessory minerals there are also present zoisite, muscovite, chlorite, apatite, rutile, zircon, and iron ores.

The orthoclase and the albite crystals are considerably altered, being filled with small inclusions which appear to be for the most part muscovite and zoisite. The small crystals of microcline, however, which occur on the borders of these decayed feldspars, in association with micropegmatite and recrystallized quartz, are always fresh.

The olive-brown biotites occur mainly in small disconnected wisps which are roughly parallel to the trace of banding in the rock. The partial alteration of this biotite has produced chlorite and perhaps epidote zoisite. The greater part of the epidote in the rock occurs in streaks, associated with muscovite, hematite, shreds of biotite, and bits of rutile which have probably been derived from the simultaneous decay of the feldspars and ferro-magnesian minerals.

Originally this granite was probably composed of quartz, orthoclase, albite, and biotite, with a few rarer minerals. Changes which must have taken place under deep-seated conditions, and others which characterize the zone of fracture, have more or less changed these components and have developed new minerals out of the old material.

In the zone of anamorphism, heavy stresses caused the granulation and recrystallization of a part of the rock, particularly in certain narrow zones. This produced fine-grained streaks of quartz and microcline crystals with roughly parallel micas of secondary origin. At this time also the epidote and most of the other secondary minerals were probably produced and were grouped in the seams in which they now appear.

The subsequent changes occurring above the zone of flowage have been slight. Chlorite began to develop out of biotite and some slight advance was made in kaolinization of the feldspars, but the results are small.

Red gneissoid granite, No. 32.—This is one of the darker phases of the granites which have been intruded into the older gneisses and schists in the T'ai-shan complex. Specimen collected along the great stairway up the T'ai-shan, at an elevation of 4,600 feet, 1,400 meters, above sea-level.

The rock is similar to the last, but presents details worthy of special notice.

Both the potash and the soda feldspars have developed microcline twinning. This feature frequently appears in only a portion of the crystals, while the remainder retains its original character. As a rule the albites

are full of inclusions of secondary minerals, but in those areas which show microcline structure, these inclusions are entirely absent and the mineral appears clear and fresh.* It is also noteworthy that these clear areas have a lower index of refraction than the decayed albite, thus indicating that the latter has undergone a chemical change as well as a structural one. Williams, in discussing the acid rocks of the Marquette district† expresses the belief that the microcline is not recrystallized, but is merely a feldspar which has undergone mechanical deformation. Bayley, however, in treating of the same rocks‡ inclines to the view that the microcline has entirely recrystallized, and in support of this idea cites its freedom from alteration products and its habitual occurrence as a component of the quartzose mosaic, which is evidently of secondary origin. I am inclined to think that Bayley is right in the majority of cases. But, as will be mentioned later, it seems highly probable that microcline does sometimes develop in orthoclase as the result of mere compression.

In certain orthoclase crystals here, there are wavy branching seams filled with a feldspathic material which has a different orientation from that of the original crystal (Plate LIV, Fig. B). The seams are roughly parallel to one another, and are so arranged with reference to the zones of shearing in the adjacent rock as to make it seem probable that they were fissures developed by a tensional strain operating at a considerable angle to the prevailing direction of the seams. The hypothesis is here advanced that they are actually tension cracks which have been subsequently or simultaneously cemented with a more sodic feldspar. The higher index of refraction of this material shows that it is not orthoclase, but probably albite. In many cases it is possible to trace the material in the seams out into coalescence with the recrystallized feldspar of the mosaic surrounding the large orthoclase, thus showing that the filling of the fissures is identical with this mosaic.

This granite shows evidence of mechanical strain in a higher degree than do those previously described. Along their edges the quartzes and feldspars are frequently granulated, especially in certain roughly parallel zones. Much of the detritus thus produced has recrystallized, forming streaks of clear quartz-and-feldspar mosaic. In these zones microcline is one of the commonest constituents. The quartzes which have not been actually granulated are elongated and show undulatory extinction very strongly, indicating that they are heavily strained. Many adjacent crystals have been ruptured and the parts separated, while others have been bent

* Van Hise describes the same conditions in decayed orthoclase. (U. S. G. S. Ann. Rep. XV, p. 503.)

† U. S. G. S. Bull. 62, pages 210 and 216.

‡ U. S. G. S. Monograph XXVIII, p. 173.

and partly sheared. Several of the albite crystals exhibit this latter feature plainly.

The biotite in No. 32 is olive-green. Certain short brownish prisms which are included in crystals of epidote are thought to be allanite.

Among the iron ores hematite is less abundant than in the red granite last described, but on the other hand there is a greater amount of ilmenite, which is often surrounded by narrow borders of titanite.

Light biotitic granite, No. 33.—This is one of the lighter phases of the granites of the T'ai-shan. Although it is believed to be younger than the gneisses, we have no information regarding its relation to the other granites of the complex. Specimen collected about 400 feet, 120 meters, lower in the ravine in which No. 32 was taken.

A pale brownish-gray granite of medium grain and uniform texture. Gneissic banding is not visible in this rock. Numerous shining faces prove on inspection to be those of glassy feldspars. This mineral, together with quartz, constitutes all but a small part of the rock. The remaining accessories are biotite, chlorite, epidote, and magnetite.

Three feldspars are present, viz, orthoclase, albite, and microcline. The albites are filled with minute inclusions, consisting of saussurite minerals, epidote, zoisite, mica, etc. In some of the most altered of these albites there are irregular bodies of quartz and limpid fresh microcline feldspar, both of which have evidently been produced by changes affecting the original albite. The orthoclases, on the other hand, are but little altered; while the microcline is always fresh. Some of the orthoclase crystals exhibit the structures which have been described under No. 32 as being due probably to tensional strains (see Plate LIV, Fig. A).

The biotite, which is present in small quantity, is very largely altered to chlorite and epidote. The epidote also occurs in grains and irregular crystals throughout the rock, and is probably the most abundant of all the darker minerals.

Pale epidote granite, No. 26.—This light-colored granite is merely another phase of the younger rocks of the T'ai-shan complex. Its field relations were not satisfactorily observed. Specimen collected on the summit of the T'ai-shan, at an exposure about 200 feet, 60 meters, west of the temple of Confucius.

This is a rather fine-grained light-colored granite, with a faint reddish hue. Greenish blotches, which appear in certain parts of the rocks, are epidote and chlorite. There is no visible banding.

The rock is composed almost entirely of quartz and feldspars. The darker minerals are epidote with a little chlorite and iron ores. Apatite, and probably allanite, are very rare accessories.

The feldspars are represented chiefly by orthoclase and microcline, with numerous crystals of albite. Although the feldspars appear a trifle dusty in the thin section, they have suffered very little alteration.

The epidote is scattered indiscriminately in the form of grains or prisms with distinct terminations. Many of these are bordered with ocherous deposits of limonite, which is evidently a decomposition product. Chlorite occurs in greenish plates as a pseudomorph after biotite, and also in little clusters of roughly parallel quadratic plates, associated with epidote and titaniferous iron ore. The presence of titanium is inferred from the fact that borders of leucoxene surround many of these black crystals.

Of the accessory minerals allanite is occasionally found as deep brown prisms inclosed in epidote. There is a surprising dearth of apatite, rutile, and other rarer constituents generally present in granites.

This rock plainly shows the effects of mechanical deformation. The quartz and feldspar grains have, in many instances, been fractured, and granulation is prevalent everywhere in the slide. The recrystallization of a portion of the granulated material has produced the so-called mortar of fresh quartz and feldspars surrounding the original grains. All three of the varieties of feldspars are represented in this recrystallized cement, but microcline is particularly characteristic of such situations. Some of the original feldspars have been fractured and the fragments have been either shifted or in other cases actually pulled apart. Fissures developed in this way have been subsequently filled with a granular cement of quartz and feldspar with which are frequently associated grains of epidote. Another effect of strain is seen in the bent laminæ of some of the albites. As would be expected both quartz and feldspar show undulatory extinction strongly.

The original ferro-magnesian mineral of this acid granite was biotite, and in addition there may have been others. The mica is now represented only by chloritic pseudomorphs, and the epidote may have been derived from the same source.

In this granite a large portion of the substance has been rearranged in fresh crystals and even in new minerals. The changes happen to be of a kind not particularly conducive to the development of gneissic banding or schistosity, and hence the rock is massive and uniform in color.

Dark biotite granite, No. 31.—This is one of the most characteristic rocks in the slopes of the T'ai-shan, but it was not observed elsewhere in the province. It appears to have been intruded into the ancient schists and gneisses, but whether it is older or younger than the red granites was not determined. It was extensively used in the construction of the great stairway which was built during the T'ang dynasty. Specimen taken at

an elevation of 4,000 feet, 1,200 meters, above sea-level, about 400 feet, 120 meters, west of the stairway.

This is a medium-grained fresh granite which possesses no banded structure. The diverse colors of the several minerals give it an unusually variegated appearance. In a background of glassy quartz and feldspars are set abundant shining crystals of jet-black biotite. Other feldspars of a reddish color, and an abundance of light-green epidote, likewise affect the color of the mass. Upon closer inspection it is also possible to distinguish crystals of pyrite and titanite.

The rock is composed largely of orthoclase, microcline, sodic feldspar, quartz, and biotite, together with titanite and secondary epidote. The less abundant primary constituents are magnetite, pyrite, and apatite. As decomposition products developed from one or more of the foregoing minerals one finds chlorite, muscovite, and saussuritic aggregates.

The plagioclase occurs in idiomorphic prisms, many of which are twinned according to the Carlsbad law. Advanced decay of this feldspar renders a precise identification difficult, but the available data indicate that it is albite. In among these albites are packed irregular grains of quartz and other feldspars. In the process of alteration the plagioclase is being replaced by epidote, zoisite, muscovite, and the other minerals which are usually grouped under the term "saussurite."

The microcline and much of the orthoclase are almost unaltered, and are evidently secondary crystals; there are also many large altered orthoclases which appear to be primary constituents of the rock.

The quartz is filled with minute hair-like crystals, such as Hawes* considered to be rutile.

The large leaves of biotite are arranged without order. Inclusions of apatite are numerous. The mineral is partly altered to epidote and quartz and also in other cases to chlorite. As a rule the epidote occurs in rather well-formed crystals which are set abruptly into the edges of the mica flakes.

Titanite is present in unusually large reddish masses, many of which may be seen in the hand-specimen. Wherever it is adjacent to the biotite there is a narrow dark and highly pleochroic zone in the latter bordering the sphene crystals. Ilmenite and pyrite occur as usual in small irregular bodies, the former associated with the titanite. The pyrite is usually surrounded by a black border which is probably pseudomorphic magnetite.

Only a moderate amount of mechanical deformation is indicated by this slide. The quartzes have strain-shadows, the micas are frequently bent, and some of the feldspars have been fractured. In the writer's opinion the

* Mineralogy and lithology of New Hampshire, 1878, p. 45.

microscopic gash-veins in the feldspars,* which are well exemplified in this section, are additional evidence of the deformation of the original rock (see Plate LIV, Fig. C). Granulated edges border many of the quartzes and feldspars, but the bulk of the material produced by abrasion seems to have crystallized to form the fresh seams of quartz and microcline which are prominent at various points. This rearrangement of material has not gone far enough, however, to produce gneissic structure.

Greenish biotite granite, No. 25.—This is merely another phase of the dark granites represented by the last (31). It is exposed in the rear of the temple of Confucius, on the summit of the T'ai-shan.

In general it closely resembles No. 31, and evidently belongs to the same rock mass. As seen in the hand-specimen, however, the texture is finer and the different minerals are less contrasted. The feldspars and the biotites are evidently more decayed and the whole rock has taken on a dull greenish tinge.

In the greenish granite decomposition is more advanced than in No. 31. Both kinds of feldspars are filled with granular saussuritic products except in certain areas in which recrystallization has probably taken place. Here there is a mosaic of quartz and orthoclase with a little microcline and albite, in fresh crystals. Among the biotites alteration into chlorite, epidote, etc., has progressed far. In general the effects of metamorphism are similar to those already noted for No. 31.

It is not easy to explain the abundance of epidote and zoisite in these two granites. When we reflect that the feldspars are dominantly alkaline in composition, and that the other most abundant mineral is biotite, there appears to be no adequate source of calcium. We seem forced to conclude that the albite and the innumerable grains of epidote zoisite are alteration products derived from feldspars rich in lime. If this hypothesis is correct the rocks are not true granites, but are altered mica granodiorites.

SINIAN SYSTEM.

The thick series of dark limestones and shales, which von Richthofen named the "Sinische" system, is widely distributed in northern China. They range in age from Lower Cambrian to Middle Ordovician. In Shantung dark limestones compose the greater part of the system, with an aggregate thickness of about 4,500 feet, 1,350 meters. The upper layers are massive dense limestones of brown or gray colors, but in the lower portions oolitic, conglomeratic, and other unusual structures are characteristic. These lower limestones are interbedded at certain horizons with gray and green shales, and beneath them lies a series of red shales and earthy limestones (Man-t'o formation).

* For further mention of this structure see page 371 of this report.

Rocks of Sedimentary Origin.

Dolomites.

Crystalline dolomite, No. 8.—A local phase of the basal layers of the Tsi-nan formation. Specimen collected in the cliff northeast of Ch'au-mi-tién village, Shan-tung.

A pale-brown rock of even grain and fine saccharoidal texture. It feels sandy to the touch and presents numerous minute glistening faces which show that it is distinctly crystalline.

The specimen is composed almost entirely of crystals of the mineral dolomite, which are more or less perfectly rhombic in outline. The characteristic cleavage is fairly prominent, but twinning bands do not appear in the slide. Upon testing the slide with logwood stain* we find that a small amount of calcite occurs in the interstices between the grains of dolomite.

Oolitic Limestones.

No single feature of the lower Sinian limestones is more distinctive than the dark oolitic bodies which are characteristic of these rocks at certain horizons over a large area of northern China. Upon studying the specimens under the microscope we find that some are typical oolites, others show evidence of having been once oolitic, while others are problematical.

Red oolite, No. 14.—Typical oolites of red color occur in thin strata near the top of the Man-t'o (Lower Cambrian) formation. Our specimen was taken at this horizon in the summits southwest of Ch'ang-hia, Shan-tung.

This specimen represents an oolitic limestone of the familiar type and is useful as a basis from which to proceed to the discussion of the stranger phases of Chinese oolites, which are so altered that their origin has been contested. The rock is a massive red-brown limestone composed largely of small spheroidal red bodies inclosed in a matrix of clear calcite. The matrix forms only a small part of the mass, however, and its color serves merely to impart to the rock a mottled appearance.

The matrix is rather coarsely crystalline, contains no animal remains, and possesses no distinctive structure. The portions contiguous to the corpuscles are usually composed of long crystals arranged as a fringe along the circumference of the red body. These facts suggest that the matrix has either been introduced in aqueous solutions or has crystallized *in situ* since the corpuscles were formed.

* For this method of distinguishing calcite from dolomite see Lemberg, abstract in Mineralogical Magazine, VIII p. 166, or Skeats, Bull. Mus. Comp. Zool. Harvard, Geol. Series, VI, No. 2.

The red bodies range in diameter from 0.5 to 3 mm. In shape they tend toward sphericity, but they are often ellipsoidal or even irregularly rounded. They are never angular. A typical corpuscle may be described as being composed of a distinct nuclear body of crystalline calcite, surrounded by a succession of very thin concentric layers made up of particles too small to be seen even under a high power. The color of the individual rings varies from light to dark reddish-brown and thus gives the section a banded appearance. The majority of the bodies are also traversed by long irregular blotches of dark-red material which radiate out from the nucleus. Such structures are characteristic of the oolites described by Teall,* Wethered,† Harker,‡ and others.

This typical description does not apply equally well to all the corpuscles. In some the nucleus is not distinct. Some are broken and recemented; while others are cavernous, the cavities being filled with clear calcite. The ratio of prominence of the radial to the concentric structures is variable and in different cases either may eclipse the other.

This specimen also shows in many places masses of little tubules similar to those which have been named Girvanella. Wethered§ believed that tubes of this character which he found in British oolites were the remains of algæ and that in many cases at least the building of the entire oolitic body should be ascribed to them. In this case, however, the facts tend to show that the Girvanella tubes were developed independently of the formation of the corpuscles, being sometimes older and at others subsequent. They occur principally in the cement between the spheroids or in the cavities in the latter. In the second situation the concentric bands in the nodule bend out around the mass of Girvanella, as if the algæ had grown *in situ*, thus bulging the cavity and causing a distortion of the surrounding mass.

The main points of interest in this slide are: (*a*) The distinct nuclei; (*b*) The clearness of the concentric and radiate structures, and (*c*) evidence that Girvanella is not the cause of the oolitic structure but is an independent growth.

Red oolite, No. 10.—A thin local limestone in the lower part of the Man-t'o red shale formation in the hills about Ch'ang-hia. The specimen is closely similar to the last described, but presents some additional features of interest which should be mentioned.

In color this rock is more uniformly red than No. 14, because the iron oxides are freely disseminated in the matrix as well as in the oolitic bodies. There are also other impurities, such as bodies of quartz, glauconite, and

* Teall: Mem. Geol. Surv. Jurassic Rocks of Britain, III, IV, V.

† Wethered: Quar. Jour. of the Geol. Soc., London, May, 1895.

‡ Harker: Petrology for Students, p. 255, Cambridge University Press.

§ *Loc. cit.*

carbonaceous matter, and even scattered flakes of muscovite. In other respects the ground-mass of this rock resembles that of No. 14. The red oolitic bodies average smaller (0.6 to 2 mm.), but are more uniform in size and shape. In their structural features the two varieties are very similar.

The nuclei consist of irregular bodies of various kinds. Some show by shape and structure that they are bits of fossil shells (Plate LIV, Fig. E). Others are pieces of former oolites which had been broken up (Plate LIV, Fig. F). This fact alone is enough to prove the primary nature of the oolites—a fact which has been questioned in some cases. When the concentric bodies were formed the deposits must have been unconsolidated.

Another fact brought out by these slides is that the nodules have all been formed under conditions which allowed some of them to be broken after having attained full growth, and to be either recemented or to be coated with further shells of material; *i. e.*, the deposit was loose and somewhat mobile, and it became solidified only at a later date, probably by the crystallization of the calcareous mud in which the particles were embedded.

In one case a bit of black bitumen forms the center of the corpuscles. The central portion consists in others of shapeless masses of tangled Girvanella tubes (Plate LV, Fig. A), but in this rock the supposed algæ are confined to the interiors of the corpuscles and are evidently nuclei upon which the concentric layers of material were afterwards deposited. Finally, there are other nuclei of irregular shape and indefinite structure which are not recognized.

The banded outer portions of the nodules are essentially like those in No. 14. The rings consist of a carbonate (calcite?) in exceedingly fine particles, associated with more or less red hydrohematite. The bands conform to the shape of the nucleus in each case. Here also we see a variable development of the radial streaks and blotches of iron oxide, in extreme cases almost effacing the concentric bands; although very irregular in outline the individual blotches tend to have a spindle-shaped or rather wedge-shaped form, the broad end being near the margin of the corpuscle. One noteworthy fact is that these radiate features are commonest in the spherical nodules and rarest on the flat sides of the more elongate bodies; *i. e.*, they are more numerous in the situations where any expansion in the interior would produce numerous wedge-shaped fissures. Where the radial streaks are most abundant they frequently expand in crossing the darker rings in the crust and thus anastomose with adjacent streaks.

The red color is due to finely divided hydrated hematite. The occurrence of red-banded fragments in the nuclei of younger corpuscles shows that

the iron oxide was introduced during the process of building the oolitic bodies. Since the original deposition, a portion of hematite appears to have been rearranged. One result of this rearrangement was the production of the radial streaks; for whether these represent fissures filled with iron oxide or a replacement of previously existing material along these streaks, they are obviously of somewhat later age than the concentric banding which they interrupt. Here and there a corpuscle has developed a granular texture by crystallization of the calcite. In these cases the hematite has been redistributed in the form of a network, inclosing the visible grains of carbonate, to the destruction of both radial and concentric markings (Plate LV, Fig. B).

Black oolite, Nos. 17–18.—These specimens came from the black oolitic portion of the Ch'ang-hia limestone near the village of that name. They represent the typical phase of the Sinian oolites (or globulites) of east China.

In this variety an abundance of little black nodules are embedded in a dense matrix, the color of which is brownish-gray. The black nodules are seen to be coarsely crystalline and composed of a carbonate, the black color of which is probably due to the presence of carbonaceous impurities. The two specimens are alike, except that in the first there are many large corpuscles (2 to 4 mm. in diameter), while in the second the majority are no larger than mustard seed.

Under the microscope (Plate LV, Fig. D) the little nodules appear as light-brown bodies set in a clear matrix. They range from 0.25 to 4 mm. in diameter and are rounded in form, with a tendency toward spherical shape. The largest bodies are usually composed of several smaller corpuscles cemented together and all inclosed in a single crust. In addition to these spherules one of the slides contains several tapering sections which appear to be the shells of a pteropod (*Hyolithes cybele* Walcott), which is known to occur in large numbers in this formation. One of these shells contains three of the small oolitic bodies.

Both matrix and spherules of these specimens consist of a medium-grained mosaic of calcite. As a rule the spherules consist of elongate and irregular crystals of calcite, which are often arranged in rudely concentric layers or in spiral whorls surrounding the center. In the other cases the calcite is of coarser grain and possesses no definite orientation; this decrease in the number of calcite crystals occasionally reaches a limit where the corpuscle contains only a single large crystal of carbonate. Here and there in the crystal one sees little cloudy rhombs of dolomite and other crystals of the same shape which possess numerous inclusions of iron oxides and are therefore to be regarded as siderite.

Nuclei are very rarely observable, and in no case is it possible to recognize the nature of such central masses as appear. In the majority of the spherules there is also no trace of concentric rings. In many, however, the rings appear as faint lines of color which pass through the crystals of calcite without deviation (Plate LII, Fig. C). Evidently these bands of minute impurities were present in the original oolite and were simply absorbed without disturbance during the crystallization of the carbonate.*

The peripheral fringe, so prominent in some of the Chinese oolites, is absent or very poorly developed in these slides. It never consists of the long feather-like crystals which appear in No. 143, but when present at all is composed of short, radially placed grains. One of the significant features of the variety is the relation between the matrix and the spheroids: on the margins of the latter there are many crystals of calcite which protrude from the matrix into the body of the corpuscle, each individual grain being partly clear and partly brownish. This proves that the entire mass of the rock has crystallized without regard to the original structure.

These oolites of the Ch'ang-hia limestone differ from the red oolites in the absence of distinct nuclei and radial streaks, and in the feeble preservation of the concentric structure. With the waning of these features there comes a great increase in the size of the crystals and in the perfection of their forms. There can be little doubt that all these differences are connected with an advance in the crystallization of the mass.† This variety corresponds to what Zirkel‡ has termed "oolithoid." Von Richthofen, who gives an excellent account of these peculiar black bodies in the Chinese limestones, applied to them the name "globulite." He believed that they were distinct from oolites and was inclined to regard them as calcified organisms.§

Crystalline gray oolite, No. 11.—A somewhat unusual phase of the Ch'ang-hia limestone. Specimen taken from the basal portion of the formation in Man-t'o-shan near Ch'ang-hia, Shan-tung. This represents an advanced stage in the alteration of the gray oolites. Through the dense clear-gray ground-mass of this rock are scattered numerous shining

* Dr. E. Lórenthey has described a rock from near Si-ning-fu, Kan-su, which seems to resemble this specimen closely. He remarked upon the faint concentric bands observed in the crystalline nodules, but regarded them as the beginning of an oolitic structure instead of a last vestige of such a feature. (Széchenyi Expedition Report, III, p. 259.)

† An oolite, resembling these specimens in its granular texture and absence of the concentric structure, has been figured by Barbour and Torrey: American Journal of Science, 1890, XL, p. 78.

‡ Lehrbuch der Petrographie, 2te auflage, I, 485.

§ In his report (China, II, p. 223), he says: "Regarding the globulitic lime (bodies) one may only guess that they are little pellets derived from organisms. It appears that with the Primordial fauna little organic bodies of very general distribution came to rest in the calcareous deposits of the sea-floor and were calcified without leaving behind any distinctive structure."—(Translation.)

PLATE LII.

A. An elliptical oolitic body composed entirely of siderite (iron-carbonate). The original material is believed to have been calcite, but this has been replaced by the siderite. During the process of replacement, the original form and structure of the nodule have been destroyed. (Specimen 11, camera-lucida drawing, × 50, Blackwelder, page 382.)

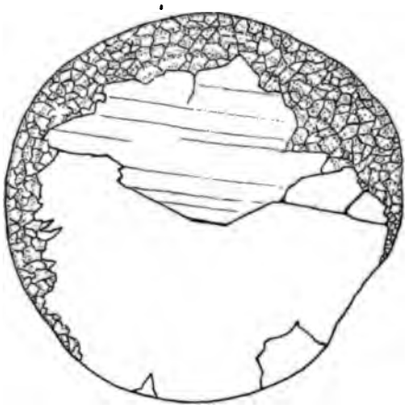
B. A partially recrystallized oolitic body. The crescent-shaped area on the upper side of the figure is composed of granular calcite, in which traces of banding are still visible. (Compare Plate LV, D.) The rest of the corpuscle is composed of a few large clear crystals of calcite which are devoid of the concentric structure. These are believed to represent a later growth than the granular portion. (Specimen 11, camera-lucida drawing, × 50, Blackwelder, page 382.)

C. A granular crystalline oolitic body. The entire rock is composed of small interlocking grains of calcite. Traces of the original concentric banding in the oolitic body are indicated by the faint dusky circles which pass through the crystals indiscriminately. The calcareous mud has crystallized, and the crystals in their growth have absorbed the streaks of impurities without disturbing their position. (See also Plate LV, D.) (Specimen 18, camera-lucida drawing, × 90, Blackwelder, page 381.)

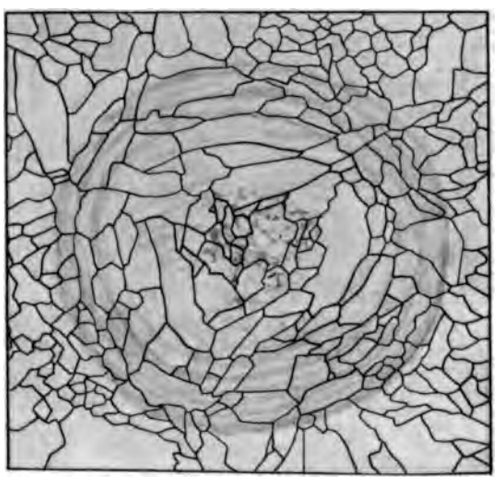
D. Periphery of a flint nodule in dolomite. The dark portion on the left is minutely granular dolomite, darkened with carbonaceous matter; this forms the mass of the rock. The rest of the circle is occupied by a portion of a spherical nodule of black flint. The lighter part is well-crystallized calcite which has been deposited in geode-like arrangement. The dotted area represents finely crystalline silica, darkened by carbonaceous impurities. (Specimen 151, camera-lucida drawing, × 40, Blackwelder, page 469.)

E. Field drawing of conglomeratic limestone showing the apparent radiate arrangement of the nodules in the plane of bedding. Sketched from a polished monumental slab on Hu-lu-shan Butte near Yen-chuang, Shan-tung. (Willis, about ½ natural size.)

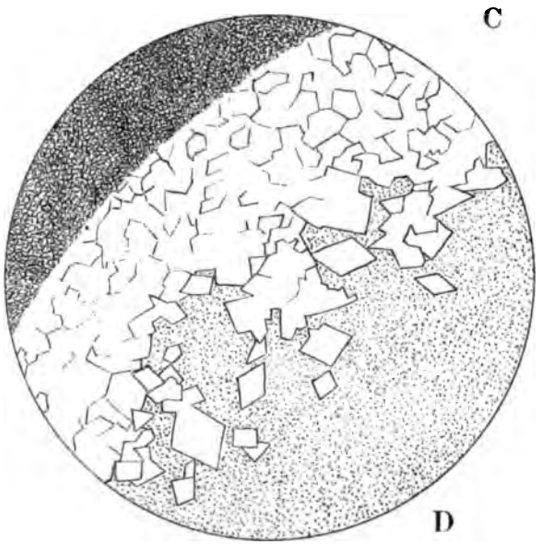
A



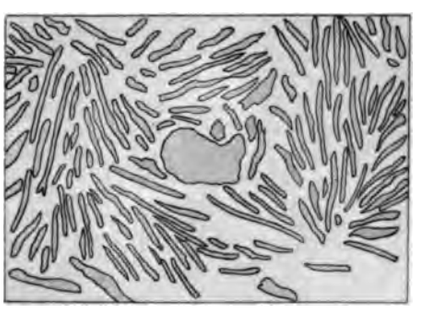
B



C



D



E

crystals of calcite and bits of green glauconite (?). Fragments of fossils are rather numerous and may be seen in the hand-specimen.

In spite of its unusual peculiarities this variety is closely related to the last described. The ground-mass is of the same character; there are fossils here and there, and even a few brown corpuscles identical with those in No. 17. The only conspicuous difference between the two relates to the coarsely crystalline bodies of clear calcite, which give this variety its porphyry-like appearance, and secondly, the large amount of siderite present in this specimen. In describing this rock it will, therefore, be sufficient to deal with these two features alone.

The siderite occurs in the form of more or less perfect rhombs, loosely aggregated and cemented with finely granular calcite. In some parts of the slide the mineral is absent, but elsewhere it is abundant; and there is no line of demarkation between the two areas. Where calcite is the dominant mineral, fossils and even oolitic structures are fairly well preserved, but in the areas of siderite such features are very rare and imperfect. On this account it is believed that the calcite was originally present, but has been replaced by the iron carbonate. These rhombic crystals of siderite are bordered with earthy limonite, and it is this alteration product which produces the ocherous blotches which appear on the surface of the rock.

The spheroidal bodies of calcite are about the size of the oolitic nodules in No. 17. Each body is made up of a single calcite crystal or of a few large interlocking grains (Plate LV, Fig. E). Grayish rhombs of dolomite are occasionally included in them, but siderite is much more abundant and in some cases has entirely replaced the calcite. Where this replacement has occurred the originally regular outline of the spherule has been much injured by the growth of the sharp angular crystals (Plate LII, Fig. A).

The size and shape of these spheroidal bodies at once suggests that they were formerly oolitic nodules; but on first inspection there appears to be nothing to verify the surmise. In this slide, however, we have proof of the transition of the undoubted oolitic bodies into spheroids consisting of one or more large crystals of calcite and lacking all of the characteristics of oolites. In a few of these bodies the process has not been completed and in one of them a crescent-shaped area, which is the remnant of a brown spherule precisely like those in No. 17, partially incloses a rounded body which consists of two to three large crystals of clear calcite (Plate LII, Fig. B). This specimen, therefore, represents a further advance in alteration beyond Nos. 17 and 18, through crystallization of the corpuscles. It is a noteworthy fact, however, that in this case the crystallization of the ground-mass has not kept pace with the changes in the oolitic bodies.

CONGLOMERATIC LIMESTONES.

In the case of these rocks I depart from the general plan of the report and discuss them collectively.

In general.—Limestones composed of pebbles set in a calcareous matrix are characteristic of the Cambrian formations in the four northern provinces of China, viz: Liau-tung, Shan-tung, Chï-li and Shan-si. In Shan-tung they occur most abundantly in the Ch'ang-hia and Ch'au-mi-tién formations, and especially near the contacts of these members with the Ku-shan shales; but they were also observed locally at other horizons from the lower part of the Man-t'o shales to the top of the Ch'au-mi-tién limestone. The rocks have already been described, in a brief way, by von Richthofen.* By him they are given the expressive name of "Wurmkalk," a term which has the advantage of not committing the author to any theory regarding the origin of the pebbles. Very recently they have been redescribed by Dr. Theo. Lorenz,† from observations made in Shan-tung. Rocks of a similar nature are reported from the Cambrian terranes of North America—notably Montana, Wyoming, Texas, Indian Territory, and the Appalachian mountains. The occurrences in the United States have been described and interpreted by Walcott‡, under the name of "intraformational conglomerates."

The conglomerate layers are associated with calcareous shales and shaly limestones. The beds themselves are rarely more than 3 or 4 feet thick, but there is frequently a succession of the conglomeratic layers separated by thin beds of shale or dense limestone, and all together forming a comparatively thick series. In a few of the conglomeratic beds, in the upper part of the Man-t'o shale, cross-bedding is sometimes observed. One important fact to be noted regarding the conglomeratic limestones is that single layers often preserve a nearly constant thickness over areas several miles in extent. Walcott§ has emphasized the fact that the conglomerates usually occur entirely within formations and thus do not mark unconformities.

The pebbles.—In the several specimens which we collected in China we find among the pebbles a wide range in size and shape. The smallest are less than 1 millimeter in length; the majority measure from 2 to 5 centimeters and the largest slightly exceed 10 centimeters. Rounded flattish forms prevail, the pebbles closely resembling the variety of gravel which consists of water-worn fragments of slaty rocks. Bodies of globular shape are not common and sharp corners are quite rare. Under the microscope it is observed that the edges of the pebbles are usually smooth and evenly

* Von Richthofen: China, vol. II, pp. 74, 79–80, 190.
† Lorenz: Beiträge zur Geol. u. Paleont. von Ostasien. Marburg, 1905, Teil 1, p. 12.
‡ Walcott, Bull. G. S. A., 1894, v, pp. 191–198.
§ *Loc. cit.*

rounded. In numerous places, however, the surfaces are rough and cavernous, indicating that the pebbles have been somewhat corroded since they were formed (Plate LIV, Fig. D).

Almost all of the pebbles are composed of very dense limestone, usually of a gray color, and, except in a few instances, devoid of fossils. In some of the specimens little rhombs of siderite and dolomite are scattered through this calcareous mass. The vast majority of the pebbles possess no distinctive structure of any kind; but in a few cases there are parallel lines suggestive of stratification. None, however, are zonally or radially built or show any traces of concretionary structures. There is also no clear evidence of organic structure. In one specimen (40) several pebbles contain horizontal layers of fragments of small trilobites and brachiopods, but they do not impart to the pebbles their distinctive features.

The color of the pebbles varies notably among the specimens. Ordinarily they are gray, frequently reddish, and less often of a greenish or yellowish hue. In one common variety (No. 5) the nodules are dark red; but when one of these bodies is broken, the color is found to be only superficial, the interior being gray like the matrix. It is as if the pebbles contained finely divided carbonates of iron, the peripheral portions of which had been altered to iron oxides by exposure to weathering.

In any one specimen the pebbles may show wide differences in color and composition. In some the calcite grains are plainly visible, while others have so dense a texture as to be opaque.

In the majority of cases the position of the pebbles is the same as in other conglomerates, *i. e.*, most of them lie with their longer axes parallel to the bedding planes of the formation, but a few, especially the shorter ones, stand at various angles to the stratification. Willis observed a slab of this limestone near Yen-chuang in which the stratified arrangement is not apparent, but rather the pebbles seem to diverge from foci as in rough radiate arrangement, and they then lie on edge, with the shortest and longest axes in the plane of bedding and the intermediate axis steeply inclined thereto. The accompanying sketch (Plate LII, Fig. E) was drawn in the field and represents a portion of the slab mentioned.

The matrix.—In general the matrix may be described as a finely crystalline mass of calcite, associated with various impurities; but in the different specimens the texture, shapes of the grains, and the abundance and nature of the extraneous material are subject to considerable variation. In the gray varieties (No. 48) the cement contains little besides the finely crystalline calcite. In the dark red rocks (No. 157) calcite is intimately associated with finely divided hydrohematite and little rhombic crystals of dolomite. In still others siderite is an important constituent of the cement, becoming

especially prominent in those varieties (No. 40) which have an ocher-colored matrix—the ocher being produced by the oxidation of the iron carbonates. Quartz grains and bits of carbon may also be found in several of the specimens.

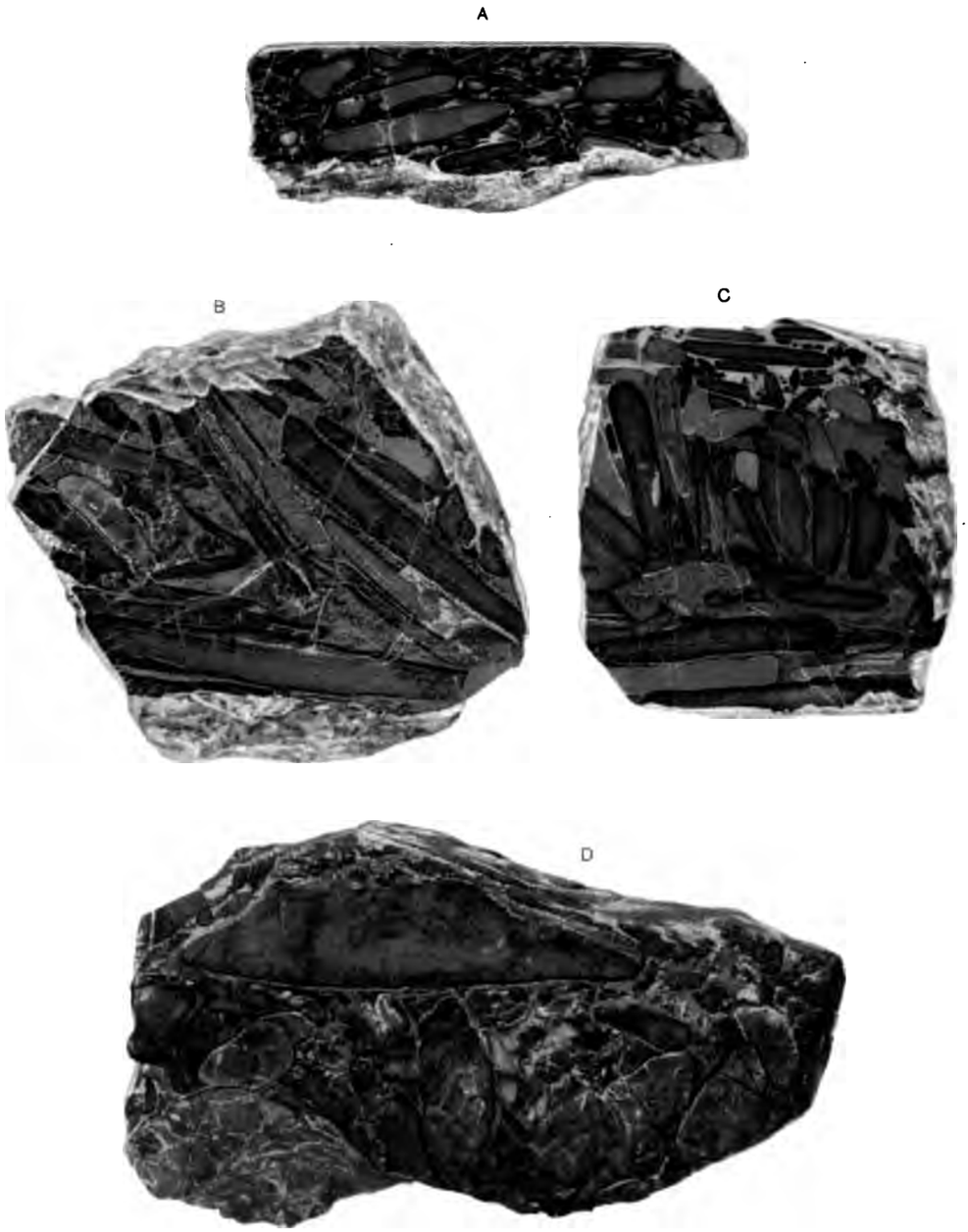
Wherever the pebbles exhibit corroded surfaces, as mentioned above, the cavities are filled with relatively coarse crystals of the cement. Siderite is especially apt to occur in such situations, probably in consequence of reactions between the calcareous cement and the ferruginous material concentrated in the peripheries of the pebbles.

Origin of the rocks.—Several hypotheses have been proposed to account for the peculiar structure of these rocks and of others similar to them which have been found in the United States. It has been suggested (*a*) that the nodules are autoclastic fragments produced by differential movements in thin-bedded, shaly limestones; (*b*) that they are concretionary bodies which have been formed *in situ* during or after the building of the rock; (*c*) that they are fossil organisms, or detached pieces or aggregations of them; (*d*) that they are pebbles derived from the breaking up of older limestones and cemented together by calcareous material; and (*e*) that they represent lenses of incipient solidification in the calcareous mud, this mud being deposited in shallow water and subject to partial disturbance and rearrangement by waves and currents.

When all of the facts are considered it is evident that the first two of these hypotheses will not stand. The fragments which compose an autoclastic, or "reibungs-breccia," are mutually similar, and the strata in which they occur show evidence of having been strongly deformed. In these conglomerates, however, the nodules are conspicuously rounded, usually having a definite position with reference to the stratification of the rock, and occur frequently in the strata which have suffered no considerable distortion. Moreover, it is inconceivable that autoclastic rocks in thin continuous layers should recur at approximately the same horizons over a territory hundreds of miles in extent.

It is equally evident that the bodies are not of a concretionary nature. They have been produced neither by the filling of cavities nor by the aggregation of material around nuclei, both of which processes tend to develop concentric structures.* On the other hand they are in all respects similar

* The local cementation of loose particles by $CaCO_3$ sometimes forms concretions in clays. This type of concretion often lacks the concentric structure, and the original stratification may not be disturbed. (Sheldon, J. M. Arms: Concretions from the Champlain Clays of the Connecticut Valley.) The production of such bodies seems to be dependent upon the circulation of ground-water in rocks elevated above the sea. The conglomeratic limestones were formed beneath the sea, as indicated by marine fossils in the matrix, and, therefore, seem to have had a different origin.



INTRAFORMATIONAL CONGLOMERATES

⅔ NATURAL SIZE

to fragments of ordinary limestone, and in some cases they are composed very largely of bits of fossil shells lying in parallel seams, precisely as in common limestones.

The third hypothesis we regard as improbable because of the lack of organic structure and of distinctive organic forms. There is nothing in our specimens which suggests that the pebbles are either individual fossils or fragments of them.* If organic at all it seems necessary to suppose that they were formed by colonies of minute protozoa or algæ whose forms have not been preserved. In the absence of any trace of organic structure the idea of such an origin must be regarded as purely speculative. It is a somewhat remarkable fact that all the conglomeratic limestones described in earlier papers belong to Cambrian terranes. It has been urged on this basis that the pebbles had the same stratigraphic significance as fossils and presumably were produced by organisms which flourished only in Cambrian times. Good examples of conglomeratic limestone, not essentially different from the Cambrian types, are now known from the lowest Algonkian terranes (Lower Huronian) of Michigan†, and from the Ordovician of Belle Isle,‡ Newfoundland, Pennsylvania, and southern Wisconsin. Brief references to "concretionary limestones" in the Belt formation (Algonkian) of Montana§ suggest a second observation of limestone conglomerate in the Pre-Cambrian rocks. It becomes evident that these pebbly limestones are by no means confined to the Cambrian, but that on the contrary they have a large range in geologic time. We must, therefore, regard their stratigraphic significance as apparent rather than real.

Upon the basis of the study of isolated specimens it appears entirely plausible to suppose that the rocks are ordinary clastic conglomerates, the contents of which were derived from the erosion of limestones unassociated with other rocks. Nothing in the detached specimens themselves is inconsistent with this view. The objections which have been raised are stratigraphic rather than petrographic. These conglomerates have not been found upon unconformable contacts, but recur at intervals through a thick series of beds, and the individual strata show remarkable uniformity in thickness over large areas. True clastic conglomerates derived from the

* Dr. Theo. Lorenz in discussing the origin of these Chinese conglomerates makes the unreserved assertion that "they are not of mechanical genesis, but organic." He first advanced the idea that they were produced by calcareous algæ, but later abandoned it and suggested the possibility that sponges were concerned in the production of them. The results of his researches seem, therefore, to be inconclusive. (*Loc. cit.*)

† Undescribed material from Kona dolomite of the Marquette district (specimen No. 45872 of the U. S. Geol. Surv. collection).

‡ Leith, C. K., unpublished notes, 1905 (specimen No. 46267, U. S. Geol. Surv. collection).

§ Peale, A. C., Paleozoic Section in the vicinity of Three Forks, Mont. Bull. U. S. G. S. 110, p. 17.

wear of exposed rocks rarely possess these characteristics,* though it is not doubted that such conglomerates may originate by the erosion of older limestones under appropriate conditions of exposure.†

The facts relating to the limestone conglomerates from Shan-tung seem to be best explained by some modification of the hypothesis suggested by Walcott‡ with reference to the American occurrences, viz, that the floor of the shallow Cambrian sea was locally raised above sea-level and eroded, the material being deposited in the areas which remained submerged. If there was actual emergence we should expect to find corresponding local unconformities, but in China none were observed. The following hypothesis, contributed by Willis, does not postulate uplift, and therefore requires no unconformities:

In true intraformational conglomerates, whether from China or the United States, the pebbles, although they are the peculiar part of the stratum, are nevertheless essentially of the same material and apparently of nearly the same episode of deposition as the matrix. Their constitution is commonly that of an earthy limestone; the matrix may be a similar limestone or limy shale. The pebbles are not derived from notably older strata, so far as one may judge from their constitution and contained fossils, nor do conditions exist which make it probable that they could have been derived from such a source by any recognized method of erosion. They have, nevertheless, usually been transported, more or less broken or worn, and redeposited. Their appearance, relations to matrix, and occurrence strongly indicate that the pebbles were originally discrete solid aggregates, not notably different in size or form from what they are in their place of final deposition. A solution of the problem of the formation of these conglomerates seems, therefore, to be probable along the line of processes, which may result in local induration of calcareous mud, independently of the solidification of the mass. The effect is one of concrescence, but the product lacks the common aspects of concretions, especially visible concentric structure.

The processes which may be suggested are chemical, physical, or organic. One essential condition of any such process is that the sediment shall not be homogeneous in the sense of being a mass of uniform chemical and physical constitution throughout. Sediment gathering beneath currents and eddies, on a bottom inhabited by various organisms, probably would not be homogeneous in that sense, but to what extent and in what manner it would be heterogeneous is a matter of local conditions which we can only conjecture.

With reference to induration through local concentration of carbonate of lime, it is no uncommon occurrence that a bed of indurated limestone lies between two beds of not indurated clay. In a less extreme case, let it be assumed that in the unconsolidated sediment lime-carbonate is passing into solution through reaction with organic matter, and diffuses itself through a certain mass. Suppose that mass to be a small thin lens

* Campbell has described, from the Cambro-Ordovician limestone of Virginia, a limestone conglomerate which rests upon an eroded surface within the formation. Here the evidence of erosion, whether terrestrial or subaqueous, seems clear. (Campbell, M. R., G. S. A. Bull., v, p. 175.)

† Pure limestone conglomerate is now forming locally in Lake Temiscaming, Ontario, through the wear of the waves upon cliffs of Silurian limestone and the lodgment of the gravel in a calcareous mud. (W. O. Hotchkiss, unpublished notes, 1905.)

‡ *Loc. cit.*, pp. 197–198.

between layers of more clayey constitution, which meet about its margin. The layers may retard or prevent diffusion, and the lenses may come to have a uniform content of lime, which is higher than that of the surrounding sediment.

Another suggestion is based on the capacity of inorganic and organic colloids to absorb carbonate of lime. Among such colloids are hydroxides of iron and alumina, organic acids, and organic gelatins. These are all present, it may be presumed, in sediments which result in calcareous, ferruginous, and fossiliferous shales. If a dilute solution of carbonate of lime, which is alkaline, comes in contact with such a colloid, a certain portion of the carbonate is absorbed.*

If it be supposed that the absorbent mass is limited vertically and horizontally (and any other distribution seems improbable) we have a local condition capable of concentrating lime carbonate in a manner to promote local induration.

Organisms, a chief source of carbonate of lime taken from sea-water, play a part in each of the preceding suggestions; they may also act independently, either by concentrating lime in their structures or by precipitating lime from solution in taking molecules of carbonic acid from the bicarbonate. In either case local concentrations may result.

Given lenses in which carbonate of lime is concentrated through any or all of these agencies or through others not here considered, a condition tending toward consolidation of the whole mass would bring about induration sooner in the local concentrations than in other parts of the mass.

I have elsewhere† described the crystallization of limestone in the Everglades of Florida, beneath the waters of shallow lagoons; and the geographic environment, in which the intraformational conglomerates of northern China and of other regions formed, may have been somewhat similar. We may conceive a shallow sea receiving fine terrigenous sediment, which accumulates so slowly as to allow opportunity for the chemical and physical reactions essential to local induration of more calcareous layers or lenses. The flats of a great river delta, in which conditions of limestone formation are combined with conditions of intermittent submergence, exposure, and silting, are appropriate. In consequence of tides and storms the muddy bottom may now be an area of deposition, now the scene of agitation. Thus the limestone sheets or lenses may yield pebbles to a practically contemporaneous deposit, and become bedded in sediment essentially like that in which they originated.

Criteria by which to discriminate between the several processes of consolidation suggested are not readily found. Chemical segregation, like that commonly assumed as the method of concretionary growth, is apparently set aside by the absence of concentric structures; yet this is not conclusive. Concretions do not always show that structure. Mr. J. M. Arms Sheldon‡ figures a concretion, which, when sawed in two vertically and polished, showed distinct lines of stratification. "But," he states, "with this exception, the mass looked perfectly homogeneous. There was not the slightest evidence of a nucleus or of concentric structure; the latter, however, developed gradually after long exposure to the air." Several other concretions figured by Mr. Sheldon exhibit stratification, which extends from the clay through the concretion continuously. The stratification of the pebbles in the conglomerate, therefore, does not remove them from the class of

* Warington: Journal, Chemical Society of London, vol. XXI, 1886.

† Conditions of sedimentation: Journal of Geology, vol. I, p. 512.

‡ Concretions from the Champlain Clays of the Connecticut Valley, by J. M. Arms Sheldon, Boston, 1900. A memoir of thirty-eight pages on a collection of about 1,400 concretions, with 160 illustrations, privately printed by the University Press, Cambridge, Mass.

concretions; neither does the apparent absence of concretionary structure. Yet, even if they be concretions, we are still unable to determine the method of formation, whether by chemical solution, diffusion and crystallization within the mass, or by physical absorption of extraneous carbonate of lime in colloids.

With reference to the organic origin of the solid lentils from which the pebbles are supposed to be derived, I am inclined to give more weight than Blackwelder attaches to the fact that the characteristic conglomerates occur very extensively in Middle and Upper Cambrian strata in China, Texas, Indian Territory, and throughout the Appalachians. They are also found in older Pre-Cambrian limestones, as well as in younger Paleozoics, but not so widely distributed as in the Cambrian, so far as we know. They occasionally exhibit a radiate arrangement such as that shown in Plate LII, Fig. E. The cases observed are few in comparison with those in which the arrangement is accidental; they may be accidents of shingling of the flat pebbles; and the fact that some such pebbles are stratified supports the view that they were originally laid flat and now occur tilted in consequence of disturbance only. But the relations in horizontal plan, shown in Plate LII, Fig. E, do not conform to any ready mechanical rearrangement and give foundation to the idea that they may represent undisturbed growths radiating irregularly from a common center. In that case the discs grew vertically as well as radially, and stood on edge in the mud.

Each of the hypothetical processes of local induration, above suggested, is possible, and any one or all of them may, together with others, be found to be that from which the conglomerates have resulted in a particular locality.

The individual specimens.—No. 5, from the base of the Ch'au-mi-tién formation near Ku-shan. The entire rock is a dense gray limestone with a faint olivaceous tinge. The pebbles are thinly coated with earthy hematite and thus appear red as they weather out upon the surface.

No. 47, from 30 feet, 9 meters, above the base of the Ch'au-mi-tién limestone, in the mountain southwest of Yen-chuang. This is similar in most respects to the first, but the matrix is more largely composed of small bits of limestone in a crystalline cement of calcite. Although the majority of the pebbles show the ferruginous red coating, in some of them this feature is entirely absent. There is considerable diversity of texture, color, and purity among the various pebbles. Some of them contain scattered rhombs of siderite which are more or less completely altered to limonite. This mineral is also found in the cement, especially in the cavities produced by corrosion of the surfaces of the pebbles.

No. 46, from the same place as the last, differs from the latter in no essential feature. The cement is more ferruginous and the red borders are absent from many of the pebbles.

No. 40, from the lower part of the Man-t'o shales, 4 miles, 6.5 kilometers, north of Sin-t'ai-hién. The red borders of the pebbles are very indistinct in this specimen, and the bright ocher color of the cement indicates a high percentage of siderite in the unweathered rock. Several of

the pebbles contain many small chips of fossils, but the great majority are entirely barren.

No. 45, from the same place as Nos. 46 and 47. The pebbles are clear-gray limestone set in an ocherous matrix. The bodies are generally long and are rather more angular than in the previous specimens.

No. 48, from the same place. This is noteworthy chiefly because most of the pebbles are very small and many of them angular. Both pebbles and matrix are of a clear-gray color and the red ferruginous borders are either very narrow or entirely absent.

No. 157, from the Man-t'o shales, near the village of Meï-yü-shan, south of Po-shan. A dark maroon-red rock in which there is no distinction in color between the pebbles and the matrix; in fact, the former are scarcely visible except on weathered surfaces. Under the microscope it is found that the pebbles consist of fine-grained limestone, being rather closely packed and cemented by limestone which contains abundant grains of quartz sand and bits of iron oxide. Both the pebbles and the matrix are filled with finely divided red hydrous hematite which imparts the dark color to the rock.

Ordinary Limestones.

Under this heading we have grouped a number of fine-grained dark limestones which represent several different terranes in the Sinian system. Some of them are entirely aphanitic and of uniform color; some are mottled, while others contain visible crystals of calcite and in some cases fossils.

Dense brown limestone, No. 9.—A characteristic phase of the Tsi-nan (Ordovician) formation in Shan-tung, and of the corresponding terranes in Manchuria and Shan-si. Specimen taken from the base of the Tsi-nan limestone at Ch'au-mi-tién.

A brown rock of aphanitic texture. It fractures irregularly and is cut by numerous small calcite veins and so-called "blind joints." This specimen contains no trace of fossils, and they are exceedingly rare throughout the formation.

Dense gray limestone, No. 7.—Specimen secured from a stratum 50 feet above the base of the Ch'au-mi-tién formation, near the village of that name. Like the next, this is one of the hard ringing gray limestones which are so common in the middle Cambrian series of eastern China.

The color is rather dark gray and uniformly plain. As in most other dense hard limestones, the habit of fracture is conchoidal. The strata are separated from each other by shaly partings of a light-green color. No fossils have been found in it.

Dense gray limestone, No. 6.—Thin limestone seams in green, purple, and yellow shales of the Ku-shan formation, in the type locality.

In most respects this closely resembles the last. The specimen is crossed by irregular vertical cracks, filled largely with limonite. When large slabs are observed it becomes evident that these represent sun-cracks, which must have been produced while the original mud was so near sea-level that it was occasionally left dry. This furnishes adequate evidence that the conglomeratic limestones, which are found at no great distance both above and below this member, were formed in very shallow water.

Mottled ferruginous limestone, No. 19.—This ferruginous gray limestone is characteristic of the upper part of the Ch'ang-hia formation in west central Shan-tung.

A dense and almost aphanitic gray limestone, with many nebulous blotches of ocher color. Fossils are rare. The thin section shows that the gray portions consist of finely granular calcite, while the ocherous blotches are composed of siderite in minute rhombic crystals partly altered to limonite. The borders of these ferruginous patches are indefinite, because the two carbonates mingle and shade off into each other very gradually. From the fact that the siderite occurs in nearly perfect crystals, while the calcite forms irregular grains, it is thought that the former is of later origin, having replaced the calcite in certain irregular areas.*

Mottled dark limestone, No. 4.—A common phase of the upper portion of the Ch'ang-hia limestone. Specimen collected near Ku-shan village.

This variety is much like the last, except that the color is varied with sooty gray instead of ocher, while the lighter portions have an olivaceous tinge. The mass consists almost entirely of finely granular calcite. Through this are scattered sections of the shells of trilobites, pteropods, and other fossils. It appears that the dark mottling is due to the irregular distribution of carbonic matter, a large amount of which is present.

Rocks of Igneous Origin.

All the rocks described here are known to occur as dikes or intrusive sheets in strata of the Sinian system and they have not been found associated with rocks of any other age. It is probable, however, that many of them are contemporaneous with the intrusions which pierce the Carboniferous and younger terranes.

The intrusions which we observed in the Sinian rocks were porphyries of syenitic or dacitic character with a few basaltic varieties. The syenites exhibit variations which approach monzonites, granites, and diorites respectively. The available exposures of the dikes and sills were deeply weathered, and it was difficult to secure satisfactory material for study. On this account the identifications are not in all cases free from question.

* See oolitic limestone, No. 11, p. 382.

BASALTIC ROCKS.

Altered basalt porphyry, No. 24.—Although this rock was found only as an intrusive in the Archean rocks of the T'ai-shan, where no Paleozoic rocks are present to act as time-indicators, it is so much like other basic intrusives, which are known to penetrate the Sinian strata in this part of the province, that the rock has been placed in this category rather than with the T'ai-shan complex. Specimen obtained from a vertical dike, 7 feet thick, on the east side of the summit of the T'ai-shan, at an elevation of about 4,300 feet, 1,280 meters.

A very dark aphanitic rock in which the only visible features are certain pale-greenish blotches with indefinite outlines.

The microscope shows the texture of the rock to be rather fine and roughly ophitic. The small but somewhat irregular laths of feldspar are embedded in a mass of augite containing grains of iron ores. The greenish blotches seen in the hand-specimen prove to be altered phenocrysts of plagioclase.

The essential minerals of the rock, in the order of their crystallization, are labradorite, ilmenite (with magnetite and pyrite), and augite. As decomposition products, there are also kaolinitic materials, chlorite, biotite, and leucoxene.

The feldspars vary in size from minute lath-shaped crystals to idiomorphic phenocrysts which are several millimeters in breadth. The decay of the feldspars, and particularly the larger crystals, to clear fibrous kaolinitic aggregates has gone so far as to render the twinning bands invisible in most cases.

The pale augite crystals are prevailingly allotriomorphic and frequently twinned. Much of this pyroxene is fresh as compared with the feldspars, but in places it has been altered, either marginally or more or less completely, to a pale greenish or yellowish fibrous material (probably delessite) with numerous specks of the iron ores.

The ilmenite occurs in irregular grains and clusters which are, in most cases, difficult to distinguish from magnetite, the presence of which is indicated by the quadratic shapes of certain crystals. Some of the ilmenite grains are bordered with leucoxene, but this feature is by no means prominent.

The biotite occurs now only in very small irregular scales. It seems to have been more abundant formerly and to have contributed largely to the production of the chloritic decomposition products. From the frequent association of this biotite with pyroxene and iron ores, it is thought that the mica may have developed secondarily in contact with these two minerals—the so-called biotite "reaction rims" of certain petrologists.

Altered basalt, No. 43.—This rock occurs as an intrusion in the Man-t'o shales near Kau-kia-p'u, 8.5 miles, 13.5 kilometers, north of Sin-t'ai-hién.

An aphanitic blackish rock resembling No. 24 in general appearance. The lighter blotches which occur in the rock are whitish instead of greenish and exhibit prominent cleavage faces.

The matrix of the rock is a mat of minute plagioclase needles with grains of augite and magnetite. Decomposition products, such as calcite and fibrous greenish and yellowish minerals, contribute largely to the formation of this ground-mass. The larger bodies in the rock are of variable size, and, regardless of the question as to whether they are phenocrysts or amygdules, they now consist almost entirely of calcite, with, in some cases, a fibrous chloritic substance and chalcedony. The majority of these bodies are more or less round or irregular in outline, but others have fairly definite crystal forms which are identical with those of feldspars. These crystals were probably plagioclases which have been thoroughly decayed and replaced by calcite.

The plagioclase of the ground-mass seems to be labradorite, but the crystals are so small and extensively altered that the identification can not be relied upon.

The augite grains are very small and are more or less altered to greenish substances. As is usual in basaltic rocks, magnetite partly altered to martite is abundant in the form of small grains. Throughout the rock there is an abundance of calcite in formless plates and clusters. It is doubtless a result of the weathering of the feldspars and pyroxenes of the original basalt.

Dacites.

Hornblende-dacite porphyry, No. 44.—This porphyry is known only as an intrusive in the Sinian limestone north of Sin-t'ai-hién. It resembles, however, certain dike-rocks which are associated with the Carboniferous formation, a few miles farther north, and we infer from this that it belongs to the same period of volcanic activity. Specimen from an intrusive sheet about 100 feet, 30 meters, in thickness, near the base of the Tsi-nan dolomite, 9.5 miles, 15 kilometers, north of Sin-t'ai-hién. At the contact of this porphyry with the overlying limestones, there is very little evidence of the metamorphism which would be expected.

Our specimen is so much decayed that it can not be considered a fair representative of the rock. There is an olive-gray ground-mass through which needles of hornblende and larger crystals of white feldspar are profusely distributed. These phenocrysts rarely exceed 3 millimeters in breadth. The ground-mass is microcrystalline and deeply decayed. It

appears to consist of feldspars in minute irregular grains, together with some quartz and a ferro-magnesian constituent.

The plainly visible crystals consist of plagioclase, hornblende, quartz, and decomposition products probably derived from biotite. Iron ores are rather abundant in small particles.

The composition of the plagioclase appears to be intermediate and sodic rather than calcic. The crystals are idiomorphic, but are now so completely altered to brownish-gray saussurite and kaolin as to make identification impracticable.

The hornblende crystallized earlier than the feldspar, as is shown by the fact that it is occasionally included in phenocrysts of the latter. It occurs, however, in much smaller and less regular crystals. Where least decayed the hornblende is bright green and moderately pleochroic, but the katamorphic alterations into chlorite, serpentine (?), etc., have reached an advanced stage.

The least abundant of the three minerals which occur as phenocrysts are fibrous yellowish-brown plates, consisting of chloritic or serpentinous products. The shapes and cleavage of these bodies suggest that they are altered scales of biotite, but none of the original substance remains to verify the inference.

Quartz occurs sporadically in small irregular bodies scattered through the ground-mass. Magnetite appears to be the only iron ore present which is primary in origin.

Hornblende-dacite porphyry, No. 42.—This porphyry was found as an intrusive sheet in the shales of the Man-t'o formation north of Sin-t'ai-hién. The lava seems to have had but little effect upon adjacent sediments. Within a few inches of the porphyry the shales are somewhat indurated and in that narrow zone they have taken on slaty cleavage, but otherwise the effect seems to have been slight. Specimen from an intrusive sheet 12 feet, 3.5 meters, thick and 100 feet, 30 meters, in breadth, 1.6 miles, 2.5 kilometers, east-southeast of Kau-kia-p'u.

In this variety we find a close approach to the monzonite porphyries of Brögger. It is much like No. 44 and is doubtless a result of the rise of the same magma. The hand-specimen shows a dark-gray rock through which are scattered abundant moderate-sized phenocrysts of pale feldspar.

The microscope reveals a finely granular ground-mass and altered phenocrysts of feldspar, hornblende, and mica, together with small amounts of iron ores, apatite, and zircon. The constituents of the ground-mass are not easily distinguished from each other. The minute clear granules are in part, at least, quartz; while another large component is a limpid feldspar whose low index of refraction indicates that it is dominantly alkaline.

The plagioclase in the phenocrysts belongs to the oligoclase-andesine series. Many of the crystals are zonally built, and in these the peripheral portions are albite. An unusual feature of many of these plagioclases is the absence or indefinite character of the twinning lamellæ; in the case of such crystals the index of refraction furnished almost the only means of distinguishing them from orthoclase. The alteration of the feldspar to kaolin has made considerable progress especially along the edges of the crystals.

The hornblende seems to have preceded the feldspars in time of crystallization. In this specimen the mineral is almost wholly changed to green chlorite, calcite, and iron ores, with a little quartz. So complete is this change that the identification of the hornblende rests principally on the characteristic crystal forms of the pseudomorphs. During the weathering of the hornblende the magnetite gathers along the cracks and edges of the crystals, or, in association with calcite and quartz, it forms clusters of grains in the interior of the hornblende bodies.

The biotite is also entirely decayed into chlorite, calcite, etc., and is now recognizable only by its tabular and hexagonal forms and the peculiar cleavage, both of which characteristics the pseudomorphs still preserve. During the alteration to chlorite numerous bits of iron ores, little prisms of rutile, and other minerals, have separated out of the biotite in the form of inclusions. The forms of some of these minute bodies are strongly suggestive of another titanium mineral—anatase. From the relations of the calcite to the chlorite it appears that the former has resulted from the decomposition of the latter—a well-known reaction in the belt of weathering. The expansion of volume which takes place in consequence of this production of calcite has caused the bending and crushing of the chlorite fibers adjacent to the lenticular bodies of the carbonate.

Both magnetite and ilmenite occur as primary constituents of the rock, the ilmenite showing considerable alteration to leucoxene.

Syenitic Porphyries.

Altered syenite porphyry, No. 16.—This hornblende porphyry was found in the form of intrusive sheets in the lower part of the Cambrian shales, east of the village of Ch'ang-hia. Usually there are several sills at different horizons in the shales. In no case did the adjacent sediments show prominently the effects of contact metamorphism by the intrusion.

A greenish-gray aphanitic rock through which are distributed decayed phenocrysts. Many of these crystals are very long and plainly show the diamond-shaped cross-sections characteristic of minerals of the hornblende group. The rock is obviously much altered. Small laths of feldspar,

grains of magnetite and ilmenite, little rods of hornblende, and irregular bits of yellowish-green alteration products form the mass of the rock.

The feldspars occur in small lath-shaped crystals, the great majority of which are Carlsbad twins. By far the commonest variety is orthoclase. The few striated feldspars seem to be oligoclase. Alterations to kaolin (?) and similar products have not proceeded far in either case.

The original ferro-magnesian mineral of the ground-mass was doubtless a green hornblende, numerous traces of which still remain in the form of little irregular rod-like prisms. It is now, however, almost entirely replaced by a yellowish-green chloritic substance. The large phenocrysts of hornblende are likewise thoroughly decayed. Their places are now taken by pseudomorphs of coarse-grained calcite and other minerals; along the margins of the phenocrysts numerous radiating bunches of fibrous actinolite penetrate the calcite, and various irregular strips and patches of yellowish and greenish alteration products are also scattered about. Among these are distributed bits of the original hornblende, which are embedded in the calcite, preserving their former orientation and cleavage. These fragments are still pleochroic.

Altered syenite porphyry, No. 23.—Essentially similar in its occurrence to the last rock described. Specimen from a thin sill in Man-t'o shales 5 miles, 8 kilometers, east of Ch'ang-hia.

Differs from No. 16 in no essential feature. The feldspars are less altered; they have low refractive indices and also low extinction angles. The striated feldspars are probably albite or oligoclase, but there can be little doubt that orthoclase is present in greater abundance.

Quartz-syenite porphyry, No. 3.—The only known occurrence of the rock is in the foothills southwest of Tsi-nan-fu, where it cuts across the Tsi-nan limestone. The specimen comes from a dike 2 feet wide on the north side of the col, 2.5 miles, 4 kilometers, WSW. of the west gate of Tsi-nan-fu.

The composition of this rock would permit its being placed in any one of several groups, as those groups are usually defined. If the granites are considered to be alkali-feldspar rocks, this might well be grouped among them, except for the scarcity of quartz. By others it might be considered a monzonite, on account of the very considerable amount of oligoclase and the scarcity of quartz. From the description the reader will perceive that with a slight decrease in the percentage of plagioclase and quartz, this rock would approximate in composition the syenites (16 and 23), while a slight increase in the amount of lime would bring it close to the dacites (42 and 44). Thus it appears that all of these intrusions might readily have sprung from a single general magma, in which there were slight variations of composition.

The rock is pinkish-gray, finely crystalline, and includes a few scattered phenocrysts of plagioclase and hornblende. The greater part of the mass consists of closely packed, irregular grains of feldspar with a subordinate amount of quartz. The less common primary minerals are pyroxene, magnetite, sphene, and apatite.

Orthoclase is the commonest of the feldspars. It occurs in irregular crystals which are partially altered. The plagioclases are rich in soda and some of the crystals are zonally built, having basic oligoclase in the center with peripheral shells of albite. The only large phenocryst occurring in the section is oligoclase. On the whole, therefore, the alkali feldspars predominate.

Although quartz is decidedly a subordinate mineral in this rock it is rather common in the form of small interstitial grains.

The amphibole is a pale-green, slightly pleochroic hornblende, which occurs in irregular crystals. It is now partly altered to greenish chlorite which is easily confused with the remaining hornblende, except when crossed nicols are used. In addition to the chlorite there are other alteration products such as iron ores and calcite, with a little epidote. It is not unlikely that the calcite is partly a product of subsequent changes in the chlorite. In several cases the hornblende incloses areas of colorless pyroxene. The character of the latter is much obscured by specks of iron ores and alteration products.

Altered quartz-syenite porphyry, No. 13.—The rock occurs as a rather thick intrusive sheet in soft shales and thin limestones of the Man-t'o formation (Cambrian) on the southeast slope of the Man-t'o butte. This is a phase of the hornblende porphyries which are common in the basal shales of the Cambrian series, in the region of Ch'ang-hia. Most of these intrusions have an abundance of plainly visible hornblende needles lying in an aphanitic ground-mass. The outcrops are so deeply weathered that in most cases we were unable to secure coherent specimens.

A dull greenish-gray finely crystalline rock, weathering to a brownish color on exteriors. Phenocrysts are ordinarily not noticeable, but moderate-sized crystals of hornblende, with a very few much larger ones of quartz, are scattered here and there. This rock does not differ widely from the quartz syenite (3). Quartz is somewhat less abundant, there are no traces of pyroxene, and lime-bearing feldspars are not present in noteworthy amount. Most of the feldspars appear to be albite with considerable orthoclase. Although the feldspars are only partially altered to kaolin, sericite, etc., the hornblendes are so completely decayed that it would hardly be possible to identify this mineral if it occurred in allotriomorphic masses. Fortunately there are in this slide numerous sharp rhombic and prismatic sections which are unmistakable. In some cases the sites of the horn-

blende crystals have been replaced only by calcite, chlorite, quartz, and iron ores, but in the great majority of cases these alteration products are obscured by an opaque brownish clay, the nature of which is not apparent; this is evidently one of the end products of weathering.

THE POST-SINIAN FORMATIONS.

The stratified rocks of this age consist of clastic sediments which are probably for the most part non-marine in origin. They are separated from the underlying Sinian system by a pronounced unconformity. In central Shan-tung two well-defined phases of these rocks have been differentiated; an upper series of shales, sandstones, and conglomerates which are prevailingly red, and a lower coal-bearing series of shales and sandstones in which the colors are variable, but seldom red. The former of these has been named the "Sin-t'ai series" and the latter the "Po-shan series."

With these sedimentary strata there are associated in several localities numerous volcanic rocks. They occur mostly in dikes, but also in the form of flows and intruded sheets. Connected with these eruptives there are also fine-grained stratified tuffs.

ROCKS OF SEDIMENTARY ORIGIN.

PSEPHITES.

Pink limestone breccia, No. 39.—These reddish breccias occur in several layers interbedded with red clay at Sin-t'ai-hién and northeast of Yen-chuang. In many cases the pebbles are more rounded than our specimen and the rock would perhaps be called conglomerate. Such conglomerate horizons are numerous in the upper part of the Sin-t'ai formation. Specimen collected in the river bluffs, 1 mile east of Sin-t'ai-hién.

A rock of unusual appearance, composed of angular fragments of dark dolomitic limestone embedded in a light reddish matrix which is also calcareous. The pieces of limestone are mostly dense brown, drab, and purplish-gray rocks, like those which make up the Tsi-nan* division of the Sinian system. It is evident that almost all of the debris has been derived from that formation. In addition to these pieces of limestone bits of chert and grains of quartz are occasionally visible. The fragments are not closely packed together and they show no traces of stratification. The rock appears to be limestone rubble cemented by calcareous tufa.

The matrix is composed of very fine-grained calcite, associated with an earthy ferruginous matter which imparts to it its reddish color. The matrix has a porous or cavernous structure in which, however, we can see no trace of organic features; all openings have been sealed with transparent calcite.

* See brown limestone, No. 9.

PSAMMITES.

Purplish-gray sandstone, No. 51.—This sandstone is probably a part of the Po-shan coal-bearing formation. A stratum, several feet in thickness, was found associated with grayish tuffs and basaltic flows, about 2 miles, 3 kilometers, northeast of Yen-chuang.

A rather fine-grained compact sandstone of a dark purplish-gray color. Most of the rock consists of rounded and subangular quartz grains which have been enlarged peripherally and cemented together by quartz subsequently deposited upon them. The less common constituents are grains of flint and iron ores; and the dark color of the rock is occasioned by the presence, in the cement, of limonite, hematite, and other dark impurities.

Impure calcareous sandstones, No. 38.—Forms thin strata interbedded with gray sandy shales in the middle member of the Sin-t'ai series. The sandstone is used locally in the manufacture of millstones. Specimen collected 4 miles, 6.5 kilometers, south of Sin-t'ai-hién.

A dull-gray friable sandstone of rather coarse texture. The thin section shows the rock to be composed of sand-grains of various sizes, cemented together by cloudy calcite, together with a subordinate amount of clay-like matter. The grains are either subangular or fairly well rounded. The majority of them are quartz, but there are several additional varieties, which are given approximately in the order of their abundance as follows: limestone, feldspar, flint, decayed ferro-magnesian minerals, and iron ores.

CARBONATE ROCKS.

Pale pink limestone, No. 41.—This peculiar limestone is a rather uncommon phase of the red beds of the Sin-t'ai formation. The limestone occurs as strata interbedded with the red shales in the upper part of the series, 3.5 miles, 5.5 kilometers, west of Sin-t'ai-hién, Shan-tung.

An aphanitic creamy pink limestone with irregular or conchoidal fracture. It includes numerous small seams and irregular cavities which are partially or wholly filled with drusy calcite crystals.

Although the mass is exceedingly dense yet it is visibly granular, the cavities mentioned having been filled with calcite deposited in the form of concentric linings. The greater part of the rock is without definite structure, but here and there one sees certain indistinct features which appear to be bits of fossils. There is nothing, however, which is recognizably organic.

ROCKS OF IGNEOUS ORIGIN.

The igneous rocks which are associated with the Carboniferous strata in Shan-tung vary from such intermediate types as dacites and syenites to ultrabasic lavas; rhyolites were not observed. By far the most common

rocks are basalts and syenite porphyries. They occur for the most part in the form of dikes and sills, but some of the basalts form extrusive lava flows. In regard to age, some of them are contemporaneous with the Po-shan series, while others evidently appeared later than even the Sin-t'ai beds. The entire volcanic epoch, however, is very remote from the present. Since that time the region has been deeply eroded, so that all trace of the old volcanoes and lava flows as topographic features has long since disappeared.

SYENITE PORPHYRIES.

Augite-syenite porphyry, No. 55.—This gray syenite porphyry occurs in the form of large dikes cutting across the red sandstones of the Sin-t'ai formation, southeast of Chóu-ts'un. Richthofen observed this rock during his journey from Chóu-ts'un to Po-shan and described it as a "basic eruptive rock of porphyritic character, with a dark ground-mass and crystals of light feldspar."* The rock differs from the porphyries in the vicinity of Yen-chuang chiefly in the fact that the ferro-magnesian mineral is augite rather than hornblende. The chemical composition is doubtless not notably different in the two cases. Specimen collected from a 10-foot, 3-meter, dike in red sandstones, 6 miles, 9.5 kilometers, southeast of Chóu-ts'un, on the main road to Tzï-ch'uan-hién.

A dark-gray porphyry in which the majority of the phenocrysts are gray feldspars and the rest are black augite. These phenocrysts are for the most part small, not exceeding 2 or 3 millimeters in breadth. Internally the rock consists of a matted ground-mass of alkali feldspars, associated with various other minerals in subordinate amount. Inasmuch as the ground-mass is visibly crystalline and the majority of the feldspars alkaline in composition, the name "syenite porphyry" seems most appropriate.

The phenocrysts of plagioclase are decidedly idiomorphic and twinning according to the Carlsbad law is common. They are now so much altered that it is difficult to identify them with certainty. The extinction angles, however, indicate that the composition is near that of labradorite. The alteration of this feldspar produces the usual grayish material of which kaolin appears to be the principal constituent.

The augite phenocrysts are not numerous and seldom show their proper crystal forms. They also differ from the feldspars in the fact that they are but little decayed. Large primary crystals of magnetite are usually associated with these phenocrysts of pyroxene, but in the rest of the rock it is abundant only in small grains.

The ground-mass consists largely of an intergrowth of irregular laths of feldspar which is unstriated and which possesses a very low index of

* China, vol. II, page 201.

refraction. In spite of the fact that the crystals are more or less altered, there can be but little doubt that they are orthoclase. Small grains and short prisms of colorless augite are rather numerous in this ground-mass. Some of these pyroxenes have undergone alteration along their borders, resulting in the formation of epidote and a brownish or yellowish product of unknown composition.

Hornblende-syenite porphyry, No. 53.—This is one of the commonest porphyries associated with the Permo-Carboniferous strata in the region about Yen-chuang. It occurs in dikes varying from 5 to nearly 100 feet in thickness, having in the thicker dikes a somewhat coarser texture. Its relations to the other igneous rocks in the district are not known. Specimen collected from a 12-foot dike in sandstones and greenish tuffs of the Po-shan series (Carboniferous), 2 miles northeast of Yen-chuang.

A rather fine-grained porphyry in which the ground-mass is of a lavender-gray color. This is thickly set with small phenocrysts of pink feldspar and weathered hornblende. The usual pinkish tinge of the rock, as a whole, is seen to be due to the abundance of these feldspars.

The rock is composed of potash-soda feldspars and a subordinate amount of hornblende and biotite with the usual accessory minerals: iron ores, titanite, apatite, and zircon.

The most abundant phenocrysts are idiomorphic feldspars which, upon closer inspection, are found to be of two kinds. By far the larger number are striated, have a low index of refraction and moderate extinction angles; these are evidently albite. They are now almost completely altered into micaceous kaolin and clay. A few of these phenocrysts, however, are apparently orthoclase; they are of course unstriated and they are also much less altered than the albite.

The first of the important minerals to crystallize seems to have been the hornblende—a rather light-green amphibole which occurs in smaller crystals than the feldspars. In the process of alteration the hornblendes are changing to a yellowish-brown serpentinous material associated with specks of iron ores, especially along cracks and borders. Included crystals of apatite, zircon, and magnetite are rather common.

The original biotite is now very badly decayed, though it may still be recognized not only by remaining bits of the mineral itself, but by the characteristic cleavage and forms which are preserved by the pseudomorphs of iron ores and gray opaque decomposition products by which it is replaced.

The ground-mass is made up very largely of rounded or subangular grains of feldspar of nearly uniform size. In this part of the rock the ratio between the two varieties of feldspar is almost reversed, the orthoclase greatly predominating over the striated feldspar. The whole mass is

thickly sprinkled with minute specks of dark-brown micaceous ilmenite (?). The exact nature of the various grains of iron ore scattered through the rock is difficult to determine, but the fact that borders of leucoxene and sphene are frequently associated with such grains indicates ilmenite, and the inference is also supported by the presence of the independent bodies of titanite which show that the rock is rather rich in titanium.

Hornblende-syenite porphyry, No. 52.—Another of the volcanic rocks associated with the Permo-Carboniferous sediments in the region northeast of Yen-chuang. Specimen from a 2-foot, 0.6-meter, dike in tuffs and shales 2 miles, 3 kilometers, northeast of the town of Yen-chuang.

A violet-gray porphyry in which needles of hornblende are the only conspicuous phenocrysts. In addition there are also numerous pale-yellowish spots of decomposition products which are probably derived from other phenocrysts. The ground-mass itself is entirely aphanitic, and the microscope reveals in it alkali feldspars with the usual darker minerals and numerous small phenocrysts of dark-green hornblende. A suggestion of flow structure is seen in the roughly parallel arrangement of the feldspars at many points in the slide.

The dark-green crystals of hornblende are rendered even more conspicuous in the thin section by the black borders of magnetite with which they are invariably surrounded. These appear to be resorption rims developed before the solidification of the lava, rather than subsequent decomposition products. A few of the hornblende crystals inclose areas of colorless pyroxene. They are but little altered.

From their low index of refraction, small extinction angles and the absence of twinning bands it is evident that the feldspars of the ground-mass are largely orthoclase with a subordinate amount of albite. These feldspars occur in the form of lath-shaped prisms, but they are so intimately intergrown that their outlines are irregular. A peculiar feature of this rock is the wreath-like clusters of feldspar prisms, which surround many of the phenocrysts and even grains of magnetite; the laths are tangential to the inclosed body and so form whorls in the ground-mass.

The darker constituents of the ground-mass are hornblende with a little pyroxene and abundant small bodies and flakes of iron ores.

Gabbros.

Olivine-hypersthene gabbro, No. 2.—This rock, referred to by von Richthofen* as "diorite or hyperite," forms several low conical hills in the vicinity of Tsi-nan-fu. The hills are surrounded and partially buried by alluvial deposits, so that the relation of the gabbro to other rock

* China, vol. II, pages 198 and 222.

formations in the vicinity is obscured. The hills are almost entirely bare. The rock is broken by three systems of joints into quadratic blocks whose dimensions are from 4 to 8 feet, 1.2 to 2.4 meters, on the side. The weathering of the gabbro produces a black sand which forms waste slopes at the bases of the hills.

Specimen obtained at the base of a conical hill, about 60 feet, 18 meters, high, which is situated 3.7 miles, 5.9 kilometers, WNW. of the outer wall of Tsi-nan-fu.

A dull blackish-brown rock of medium granitic texture. From an inspection of the hand-specimen the nature of the darker minerals can only be guessed at, and the lighter ones appear to be entirely feldspars. The olivine, which is revealed by the microscope, is difficult to distinguish with the unaided eye. In the thin section the constituents are seen to be plagioclase, augite, hypersthene, olivine, and a little biotite and magnetite.

The first mineral to crystallize was olivine; it is found included in both of the pyroxenes and in the feldspars and is unexpectedly fresh. Along the edges and cleavage cracks, pale-greenish serpentine has begun to develop, and in some cases a little magnetite dust has separated out during the process. Where the olivine is in contact with the feldspars, one frequently sees bushy growths of minute colorless fibers which are probably tremolite or some other amphibole. Reaction rims of this character have been described by Törnebohm,* Williams,† and others.

Of the two pyroxenes hypersthene is less abundant and usually occurs in smaller bodies. It exhibits the customary pleochroism varying from pale-green to salmon-pink. It is not only unaltered, but is relatively free from inclusions.

The most common of the darker components of the rock is a pale-greenish augite. This contains numerous small inclusions of the olivine, biotite, magnetite, and other minerals. Certain inclusions which appear clear gray between crossed nicols are probably feldspars; in a few cases faint twinning bands can be seen. A mineral supposed to be rutile occurs in minute short needles, all of which lie with their axes parallel to the principal cleavage of the pyroxene. On account of the great difference between the two kinds of pyroxene in regard to their content of these inclusions, they can readily be distinguished from each other by this means alone.

The large clear prisms of feldspar crystallized later than the other components and hence are bounded by irregular lines. They show but little sign of decay and have very few inclusions. The extinction angles

* Neues Jahrbuch für Mineralogie, Geologie und Paleontologie, 1877, p. 383.

† U. S. Geological Survey, Bull. 28, p. 25.

of this plagioclase indicate that it is a labradorite having approximately the composition of Ab_2An_3.

The few irregular slabs of brown biotite seem to be primary constituents of the gabbro. Where the magnetite is contiguous to pyroxene, biotite is frequently present in what appears to be reaction rims between the two minerals. If this relation is a genetic one, as it is said to be in many rocks, some of the necessary material for the biotite has probably been furnished by the feldspar, or has been introduced from outside.

In comparison with other gabbros, magnetite is not common in this rock. In addition to its occurrence in the form of inclusions in the augite and its association with the decay of olivine, it appears somewhat rarely as irregular bodies in the interstices between other minerals.

Andesites.

Gray augite andesite, No. 49.—This specimen comes from the borders of a mass of basic intrusives 3.5 miles, 5.5 kilometers, southeast of Yen-chuang. The greater part of the rocks are of darker color and presumably of more basic composition.

A rather light-gray densely crystalline porphyry in which the phenocrysts are black augites and white feldspars. The feldspars, being so nearly the color of the ground-mass, are inconspicuous.

The ground-mass of the rock consists of stout crystals of lime-soda feldspar interlaced with augite and a little biotite. The feldspars and the pyroxenes together probably compose 90 per cent of the rock. It may be mentioned that quartz is present, but is comparatively rare.

The feldspars are zonally built and are rather calcic in composition; the average is a labradorite. They began to crystallize earlier than the pyroxenes, but are not sufficiently idiomorphic to produce a well-defined ophitic texture. Although the feldspars are relatively fresh, alteration has begun, especially in the interiors of the crystals. In such cases the altered area usually develops along zones in the crystals and takes on forms concentric to crystal outlines.

The phenocrysts of augite are comparatively rare and require no special mention. The great majority of the larger crystals are composed of a pyroxene-amphibole intergrowth. When examined in the thin section these phenocrysts are shown to be extremely complex in constitution and irregular in outline. In the majority of cases they consist of augite and labradorite intricately intergrown and usually including irregular bodies of hornblende, biotite and iron ores. The biotite and hornblende are usually concentrated near the center, but without any definite orientation, while the network of pyroxene and feldspar forms the periphery. In other cases, however, a clear body of augite is surrounded by a narrow and very

irregular border of olive-green hornblende with which is associated magnetite and biotite in small shapeless bits. The whole is inclosed, as in former cases, by a network of augite and labradorite. Evidently the inner portion of this phenocryst furnishes a case of the very familiar habit of hornblende in inclosing pyroxene. The exterior intergrowth of the augite and feldspar with the hornblende, biotite, and magnetite may be due to alternate crystallization and resorption by the still liquid magma of portions of crystals which formed during the earlier stages of cooling. Lacroix describes a similar condition which he observed in certain French lavas,* and he suggests the explanation just given.

The pyroxene of the ground-mass is a colorless augite, occurring in short prismatic bodies in which, however, the crystal faces are seldom discernible. In many instances the edges appear to have suffered corrosion. Abundant inclusions of iron ores in very small particles are characteristic of this mineral. In the incipient alteration of the pyroxene a colorless secondary chlorite is developing along the cracks and edges.

The biotite is reddish-brown and highly pleochroic. It is a primary constituent of the rock and occurs in the form of short scales which include many small bodies of titanite and iron ores. Its association with hornblende and magnetite in the irregular intergrowths of the phenocrysts has already been mentioned. In the alteration of the mica a fibrous aggregate is produced which appears to consist of a nearly colorless chlorite.

White augite andesite, No. 50.—Like the last this is a marginal phase of the massive basic intrusion southeast of Yen-chuang. The specimen was taken from the edge of the intrusion very close to its contact with the limestone.

A very fine-grained grayish-white rock in which no dark minerals are visible except as minute ill-defined specks. On the weathered exteriors phenocrysts of white feldspar may be seen, but these are almost invisible on freshly broken surfaces. It is closely allied in composition, as well as by its relation in the field, to the porphyry just described. It is more acid in composition, however, and there is a notable absence of hornblende, iron ores, micas, and other dark-colored constituents.

The rock consists essentially of a medium-grained mass of plagioclase with a little augite, the interstices between the larger crystals being filled with a considerable amount of minutely granular feldspar and quartz. Iron ores are almost entirely absent, and the ocher-colored specks, which are visible in the hand-specimen, are seen to be secondary discolorations.

The feldspar of No. 50 seems to have a higher percentage of soda than that of the augite porphyry (No. 49) and the zonal structure is not so promi-

* Lacroix: Minéralogie de la France, vol. 1, p. 668.

nent as in the other rock. The dominant feldspar is approximately oligoclase, but there is another variety present which forms more idiomorphic crystals and is probably labradorite. For the most part the feldspars are unaltered, but, where decay has begun, kaolin and probably albite may be detected among the products.

The pyroxene is a nearly colorless augite. It contains very few inclusions, and most of them are titanite and feldspars. The mineral occurs in short irregular prisms, with corroded edges. Sometimes it appears in the form of a fibrous aggregate of little columns which have a tendency toward radial or at least divergent arrangement. The alteration of the pyroxene has been slight and chlorite seems to be the principal result.

The interstices between the grains of feldspar and augite are filled with a fine-grained cement consisting of minute granules of quartz and feldspar. The former is occasionally plainly visible in medium-sized irregular bodies. It probably predominates over the feldspar, but occurs in such small grains that the two are difficult to discriminate.

Titanite is abundant in this rock in the form of irregular grains and clusters. A much rarer accessory mineral is zircon. A single crystal of the latter was seen with a grain of magnetite inclosed in it.

Basalts.

Basalts are among the commonest of the igneous rocks in central Shantung. They occur as dikes, sheets, and surface flows associated with the Carboniferous and related terranes at Yen-chuang, Po-shan, and Weï-hién.

Porphyritic basalt, No. 54.— This is one of the numerous phases of the Post-Carboniferous volcanic rocks in the coal-field of Yen-chuang. Our specimen comes from a small dike, about 2.5 feet, 0.75 meter, thick, which pierces the tuffs and sandy shales of the upper part of the Po-shan series about 2 miles, 3 kilometers, northeast of the town.

A massive blackish rock of dense aphanitic texture thickly studded with small phenocrysts of pyroxene, feldspar, and olivine. These pyroxene crystals stand out prominently upon the brownish weathered surfaces of the rock.

All of the constituents are comparatively fresh, and of these the olivine is as usual the most altered. The prominent minerals of this rock seem to have crystallized in the order which is commonly observed in basalts: (1) magnetite, (2) olivine, (3) feldspar, (4) pyroxene (Plate LV, Fig. F).

The magnetite occurs only in small bodies associated with the groundmass or inclosed in the other minerals.

Olivine occurs in abundant crystals of variable size and shape. The only inclusions which it contains are magnetite and a little brown glass. Many of the crystals are corroded about the edges, and the cavities thus

formed have been filled with the material of the ground-mass. Black "reaction rims" of magnetite surround almost all of the olivines, whether they are decayed or fresh. It thus appears that such rims are not due to a subsequent alteration of the olivine, but to reaction with the magma while it was still somewhat fluid. The alteration of the olivine to a yellowish or greenish serpentine has made some progress; although some of the smaller crystals have been completely altered, the majority have been affected only along the numerous cracks.

The feldspars are zonally built and are therefore of varying composition. A study of the extinction angles by the Michel-Lévy method indicates that the average is a labradorite having approximately the composition Ab_1An_2. In these feldspars distinct crystal forms and Carlsbad twins are usually well developed. Although inclusions of magnetite and bits of the ground-mass occur in the feldspars they are not prominent. In some cases minute inclusions are arranged in belts which are parallel to the zonary shells of which the feldspars are composed: it is inferred from this that the growth of such crystals was not continuous, but that it was arrested and subsequently continued after an interval. The alteration of the feldspars in this rock is insignificant.

The pyroxene is a pale-green augite without perceptible pleochroism. The crystals are entirely fresh, but usually present a dusty appearance as if they contained inclusions too small to be distinguished. The visible inclusions consist of magnetite, feldspar, apatite, and glass, with olivine only in rare instances. The bits of glass are either clear or brownish in color and contain abundant specks of magnetite. The augites are usually bounded by distinct crystal faces, but in many cases these regular outlines are interrupted by cavities produced by the corrosion of the magma.

The base of the ground-mass is nearly isotropic, but a higher power and the selenite plate show that it is not glassy. In this there are embedded bits of feldspars, pyroxene, and magnetite, which vary from good-sized crystals down to the vanishing point of visibility. In certain places these small crystals are so abundant that the rock appears to be almost completely, if minutely, granular. The feldspar crystals are much stouter and more irregular than is usual in basaltic rocks.*

Porphyritic basalt, No. 57.—This is the basalt mentioned by von Richthofen† as being the first which he encountered in his travels in China. Judging from the glassy character of the rock and the suggestions of pitted surfaces which were preserved on the weathered exteriors, it is part of an extrusive lava flow. The exposure is about 3 miles, 5 kilometers, southeast

* For a basalt with feldspar microlites of the usual character, see No. 57.

† China, vol. II, page 201.

of the city of Chóu-ts'un and the basalt in this case appears to overlie red and gray sediments of the Sin-t'ai series.

A stony-black lava which at first sight seems to be entirely aphanitic. A closer examination, however, reveals numerous small bits of olivine, and upon the brownish weathered surfaces pyroxene crystals also become visible.

The base of this rock is obviously glassy. In this glass are embedded abundant narrow microlites of feldspars, grains of magnetite and pyroxene, and small phenocrysts of olivine and a few of pyroxene. Most of the augite occurs in minute grains. The forms and arrangement of the feldspar prisms give the rock a very marked ophitic texture.

With the exception of the iron ores, olivine was the first mineral to crystallize. It occurs in small bodies which are frequently bounded by crystal faces, and also in minute granules which form a part of the ground-mass. Inclusions of magnetite and brown glass are rather numerous. In some cases the crystals have been somewhat corroded and the pits filled with the material of the ground-mass. The common alteration to green serpentine has only begun and is almost confined to cracks and edges.

The feldspar is labradorite, which appears uniformly as small lath-shaped microlites. A suggestion of flow structure is observed in the rude parallel arrangement of the microlites in certain areas of the slide.

The augite, which occurs occasionally in small irregular phenocrysts, is pale olive-brown and slightly pleochroic. By far the greater part of the augite, however, is in the ground-mass in the form of abundant rectangular or shapeless grains which appear yellowish in color. It seems to have been the last mineral to crystallize.

Although magnetite preceded the other minerals in time of crystallization, it occurs only in the form of minute grains distributed abundantly throughout the rock.

The glassy base which forms the matrix in which all the other constituents are embedded is usually nearly colorless; in certain areas, however, it has a brownish tinge.

Peridotites.

Altered peridotite, No. 35.—The altered peridotite occurs as a dike, 40 feet thick, which cuts vertically across red sandstones belonging to the Sin-t'ai series, about 4 miles, 6.5 kilometers, south-southwest of the town of that name. It is exposed in a barren lowland which is considerably dissected by ramifying gulleys.

Contact phenomena.—Along the contact between the green dike and the adjacent red sandstones there is a zone, 2 or 3 feet in breadth, through

which the sedimentary rock has been changed to a greenish color. At the immediate contact the sandstone has been completely cemented into a dense flinty rock, but this is only a fraction of an inch in thickness. Along this contact subsequent faulting is indicated by the prominent development of slickensides upon this quartzitic layer.

The red sandstone (represented by No. 37, which was collected at a distance of 10 feet, 3 meters, from the intrusion) is in reality a fine-grained arkose. It is composed of quartz and abundant feldspars together with grains of magnetite and occasionally other minerals. The cementing materials between the grains are earthy red hematite with calcite and a little quartz.

In the altered zone the sandstone has been changed to a dull olive-green color (No. 36, collected 3 feet, 1 meter, from the dike). The thin section shows that the only notable change which has taken place is in the cement. The slide discloses no newly developed minerals nor any alterations of the sand-grains themselves. Even the calcite appears to have remained unaltered. The earthy red hematite, however, which is so characteristic of the red sandstone is in this specimen represented by an amorphous material of dull greenish color. While it is not possible to determine microscopically just what this pigment is composed of, it is probable that it has been produced by the reduction of ferric components to the ferrous state.

In the only observed exposure of this rock it is so extensively decayed that it is difficult to obtain even a small and irregular specimen. As it appears at the surface the mass of the rock is bright green and there is usually a distinct spheroidal parting. Most of the rock can be dug like soil, but by removing the outer portions of one of the spheroids it is usually possible to obtain a small core or nucleus which is firm and coherent. This nuclear material has a dark brownish-gray color and is aphanitic. In the field it was mistaken for a badly weathered pitchstone.

An examination of the thin section shows that the rock was formerly composed almost entirely of olivine with a little pyroxene and iron ores. It was therefore very close to the dunites in composition.

The olivine in our specimen is wholly altered to fibrous gray serpentine and iron ores. The cracks and boundaries between the crystals are partly occupied by a greenish decomposition product which is probably also serpentine. The centers of many of the crystals are obscured by opaque brownish material, the nature of which is not recognized.

The section shows only a few irregular areas which are occupied by augite. It occurs in irregular masses inclosing crystals of olivine and controlled by the latter in all its boundaries. Along the cleavage lines

edges of the section of quartz are sometimes cavernous and the pits thus formed are filled with the material of the ground-mass. Inclusions of the same character in the body of the crystals are also not infrequent. These corroded edges are much more characteristic of the quartz than of the feldspar, although the latter also show the same peculiarity in some cases. Minute specks arranged in roughly parallel streaks are included in many of the quartz crystals. It is hardly possible that these are of a secondary nature, as they are said to be found in such metamorphosed rocks as the gneisses. Larger crystal inclusions are by no means common; they comprise grains of zircon, magnetite, and little olive-green tourmalines. A few of the quartzes in the porphyry exhibit the rhombic cleavage which is so rarely seen in sections of this mineral. Such crystals are traversed by zigzag cracks in two systems which make an angle of about 78° with each other.

These two systems are approximately parallel to the outlines of rhombic sections. This is so rare a characteristic of quartz that it is likely to mislead the observer at first glance into thinking that the mineral is orthoclase. The index of refraction, however, and in this case also the absence of alteration products, is amply sufficient to correct the error as soon as the crystals are more closely examined.

The ground-mass is composed of densely crowded irregular grains of feldspar and quartz. The feldspar seems to predominate in quantity over the quartz. Certain striated grains which have a low index of refraction indicate the presence of sodic plagioclase; but orthoclase is much the more abundant feldspar.

The less common components of the ground-mass are biotite, zircon, and magnetite, together with the reddish alteration products of the last. The iron ore occurs in rather numerous grains of variable size and shape, but distinctive forms are often seen among them. Formerly small flakes of biotite were not infrequent in the rock, but they have been almost wholly altered to fibrous aggregates of yellow delessite (?). The red and ocher-colored iron oxides, which have been derived in large measure from the alteration of magnetite, occur in small irregular blotches or are disseminated in thread-like stringers. The reddish hue of the rock-mass is undoubtedly due to the presence of these secondary ferruginous materials.

The absence of these visible effects of mechanical deformation such as granulation, microscopic shear-planes, strain-shadows, etc., indicate that the rock has never been subjected to the heavy stresses of the zone of anamorphism. Evidently this is part of an intrusion which crystallized at no great depth and whose subsequent history has been without notable events.

WESTERN CHÏ-LI.

Our geologic studies in Chï-li were confined almost entirely to the mountains immediately west of Pau-ting-fu. The area surveyed is represented on the atlas sheets E I to G I. In this belt gneissic rocks of the T'ai-shan complex (Archean) lie at the surface over a wide area. There are also limited outcrops of the Ta-yang (Upper Algonkian), Sinian, and Shan-si systems.

T'AI-SHAN COMPLEX (ARCHEAN).

Gneisses, schists, granites, porphyries, and a few other rocks are the constituents of the Archean of eastern China. Much of the mass has been metamorphosed past recognition and with present methods we are unable to ascertain the origin of many of the rocks. A large part is, however, clearly composed of igneous intrusives, some of which are moderately metamorphosed. In one instance only we observed unquestionable sedimentary rocks in the Archean, but there is some evidence suggestive of a similar origin for various gneisses and schists which are now classed as doubtful. The facts from China are of particular interest at present because the Archean has been held until recently to consist entirely of metamorphosed igneous material.*

Rocks of Doubtful Origin.

Gneisses and Schists.

Flesh-colored biotite gneiss, No. 81.—A member of the metamorphic complex of the Fóu-p'ing region. The geologic relations of the gneiss are not known, but its composition suggests that it is a severely metamorphosed granite. Our specimen is from the roadside 3 miles, 5 kilometers, southeast of Li-yüan-p'u.

The mass of the gneiss is pinkish-white, but dark seams of mica modify the color. It has a granular texture with poorly developed cleavage.

The light-colored minerals are chiefly quartz, orthoclase, and microcline, with a little oligoclase; while the prevalent dark mineral is biotite. The absence of iron ores is noteworthy. The banding, which is distinct in the specimen, is not so obvious in the slide.

No trace of the original constituents of the rock now remains visible; all have recrystallized. Moderate deformation subsequently is evidenced by strain-shadows, cracks, and local granulated edges. The feldspars have tension-cracks and microcline structure which are believed to be strain phenomena. Weathering has partly reduced the feldspars to kaolin and has converted many of the biotite flakes into green chlorite.

*Sedimentary rocks have been reported in recent years from the Archean (basement-complex) rocks of United States, Canada, and Europe. A summary of these occurrences appears in Bulletin of the U. S. Geological Survey, Van Hise and Leith: Correlation papers, Archean and Algonkian

Greenish chlorite gneiss, No. 80.—Another phase of the gneisses, found in close proximity to the rock last described. Its origin is wholly indeterminate.

The color of this rock is dark greenish-gray from the association of chlorite pseudomorphs with quartz and feldspar. The banding and texture are both rather fine.

The specimen is badly altered and is therefore not a true representative of the fresh rock. Quartz, feldspar, hornblende, biotite, and pyrite are the essential minerals of the rock. Of these the first is, of course, unchanged, while the second is clouded with kaolinitic products and the rest have been changed almost entirely to hydrous minerals characteristic of the belt of cementation.

The feldspars (orthoclase with less oligoclase) predominate over the quartz. Biotite and hornblende were formerly the most abundant minerals. Both have since been replaced by chlorite. The hornblende may still be seen in isolated bits inclosed in the chlorite; but the mica is recognized only by the forms of its chloritic pseudomorphs. The pyrite has likewise suffered extensive alteration to limonite.

The basic composition of the hornblende-biotite gneiss suggests that it may have been derived from an igneous mass of basaltic character.

Pale-brown hornblende gneiss, No. 71.—A very prevalent phase of the Archean gneisses in the vicinity of T'ang-hién. It is there associated with sericite schists, amphibolites, mica schists, and white marble. Although its origin can not now be determined, both its relations with the marble and its somewhat unusual composition are consistent with derivation from a sedimentary rock. The specimen comes from the hill, 2 miles,.3 kilometers west of Chuang-li (= stratum *h* in Fig. 12, Part I).

The gneiss is hard, compact, and of light color. The individual bands are ill-defined and yet the parallel structure is plain in the hand-specimen. The abundant minerals are orthoclase, quartz, albite, and green hornblende. Subordinate varieties include red garnet, epidote (with allanite), ilmenite, titanite, and zircon.

A large part of the rock possesses a granitoid texture, but it has been heavily deformed along certain sinuous planes, resulting in the production of shear-zones. In the granitoid portion the feldspars and quartz are not greatly distorted and other minerals rarely occur. The shear-zones are loci of granulation. The quartz and feldspar have been sliced and mashed into long streaks consisting of granules and lenticular shreds. Minerals adjacent to the shear-zones, when not actually broken up, show tension-cracks, bent laminæ (Plate LVI, Fig. A), and strong undulatory extinction. The darker and rarer minerals are closely associated with these shear-zones and thus

in the gneiss is suggestive of a series of limestone layers, but speculation on the subject can not be fruitful without additional facts.

Gray biotite-hornblende schist, No. 76.—In layers and lenticular bodies associated with the gneisses below Fóu-p'ing. Specimen taken from the side of the river-road 2 miles, 3 kilometers, below the city.

A gray imperfectly cleaved schist in which black and white minerals produce a minutely speckled appearance which is uniform throughout the rock. The constituents are chiefly feldspar, quartz, hornblende, and biotite, with malacolite (?), epidote, pyrite, magnetite, and tourmaline.

Orthoclase is the dominant feldspar, with oligoclase in minor quantity. The fresh brown to olive-green hornblende appears in irregular bodies intergrown with the paler components of the rock. Biotite is less abundant, but is conspicuous in the hand-specimen. The flakes are not aggregated in seams, as they are in many schists, but are distributed evenly throughout the mass.

In many respects the schist resembles the amphibolite (75) with which it is associated in the field. It contains more feldspars and biotite, and the feldspars are alkaline rather than calcic; but otherwise the relationships are close.

Rocks of Sedimentary Origin.

White quartz-muscovite schist, No. 72.—This silvery quartz schist was observed only on the northeastern slope of the hill 2 miles, 3 kilometers, west of Chuang-li (atlas sheet G I). There it is interbedded with white micaceous marble, brown biotite gneiss, etc. The marble is not represented in our collection, but its origin is undoubtedly sedimentary; and the schist is so intimately associated with the marble that we believe it had a similar origin.

A gray-white rock composed of translucent granular quartz, white muscovite, and a little orthoclase. The parallel arrangement of these minerals imparts a fairly good cleavage.

The complete recrystallization of the mass has obliterated its former constituents and structures. The changes which occur in rocks during metamorphism are still too imperfectly understood to enable us to determine the ancestral character of this schist. In the field relation, however, it occurred in seams between beds of marble as if it represented shale bands in the original limestone. If it has been produced from a shale, we must admit that profound chemical changes have taken place, resulting in an increase in quartz and a decrease in the alumina, lime, and magnesium. Changes of this magnitude are known to occur abundantly in the zone of anamorphism.

Rocks of Igneous Origin.

The granites associated with the Archean rocks are unquestionably much younger than the gneisses and schists, and they may well belong to later Algonkian time. Nevertheless it is not possible to separate them from the T'ai-shan complex in the region under discussion. They include gray biotitic and hornblendic varieties in which the feldspars are usually white. The red granites of Shan-tung are not represented here.

Granites.

Biotitic hornblende granite, No. 77.—Large dikes of this granite traverse the ancient gneisses and schists in the small valley west of Fóu-p'ing-hién. Specimen obtained from such an intrusion 4.5 miles, 7 kilometers, west of the city.

Black crystals of biotite and hornblende embedded in a mass of white quartz and feldspar impart a notably speckled aspect to the rock. The texture is medium fine and there is no banded structure.

The feldspars are albite with oligoclase. Hornblende is more abundant than biotite and is but little altered. The large flakes of biotite have changed in part to chlorite with epidote and zoisite. Magnetite, ilmenite, and sphene are clustered about the hornblendes in considerable abundance, but are not common in the feldspathic areas.

The granite bears no marks of deformation. It is probably younger than the last epoch of folding in this region. Inasmuch as the upper Algonkian strata near Fóu-p'ing lie nearly horizontally upon the Archean, that epoch may be assigned with some confidence to the Middle Algonkian, for the lower Algonkian rocks of the adjacent Wu-t'ai district are severely folded and metamorphosed.

Biotitic hornblende granite, No. 79.—Very similar to the last and evidently derived from the same magma. It occurs as a dike 70 feet, 21 meters, thick, in the Archean gneisses 4 miles, 6.5 kilometers, west of Fóu-p'ing-hién.

Contrasts in color are less conspicuous in this variety because the texture is finer and the dark minerals are more evenly distributed. The minerals are much the same in both rocks. In this variety the feldspars consist of orthoclase with a zonally built plagioclase of the albite-oligoclase group. The dark minerals and accessories require no additional mention.

Biotite-granite porphyry, No. 67.—Gray granites, represented by Nos. 67 and 68, occur abundantly in the form of medium-sized dikes in the gneisses northeast of T'ang-hién. The rock is quarried by the people and used in the manufacture of millstones. This specimen was collected from a 2-foot, 0.6-meter, dike at such a quarry 3 miles, 5 kilometers, northeast of the city.

At first glance the rock appears to be a fine-grained gray granite, but the microscope shows that it consists of a felsitic ground-mass in which numerous larger crystals of quartz, feldspar, and biotite are embedded. The largest and most conspicuous of these phenocrysts are biotite.

The matrix is an irregular granular mass of quartz and limpid feldspar, with minute shreds of biotite and secondary minerals.

Among the phenocrysts quartz and feldspar are about equally numerous, but the latter forms the larger bodies and is, therefore, present in greater volume. Both are imperfectly idiomorphic. The feldspars are chiefly orthoclase with a little microcline and oligoclase.

This specimen is extensively altered. Abundant muscovite and epidote have been produced from feldspars and biotite. The alteration of biotite to muscovite is unusual and apparently has not been recorded previously. In this slide the colorless mica may be observed feathering into the biotite after the manner of chlorite. The change involves a loss of magnesium by the biotite, but as no secondary magnesium mineral is present we can only suppose that this element has been removed in solution. All of the alterations noted appear to be those of the belt of cementation.

Biotite-granite porphyry, No. 68.—Like the last the rock was found in small dikes cutting the T'ai-shan gneisses northeast of T'ang-hién.

A clear-gray rock in which the biotite flakes are smaller and the ground-mass more aphanitic than in No. 67. It is also a much fresher specimen and therefore worthy of more detailed description.

The felsitic ground-mass is minutely and uniformly granular. In composition it resembles that of No. 67. The phenocrysts are prevailingly idiomorphic, and biotite is subordinate to quartz and feldspar.

Muscovite, epidote, and zoisite occur in small irregular bodies, frequently unassociated with the minerals from which they have been derived. In this slide, as well as in the last, partial pseudomorphs of muscovite after biotite may be observed.

Marks of deformation are limited to strain-shadows in the larger crystals and local spots of microcline grating in the feldspars. The existence of long unbroken prisms of apatite is further proof that the rock has not been severely deformed.

These granite porphyries at T'ang-hién resemble the gray granite above Fóu-p'ing-hién in their mineral constitution, except that they are devoid of hornblende. It is probable that both belong to a single episode of igneous activity in Algonkian times.

Brown hornblende-granite porphyry, No. 78.—Dikes of this porphyry were observed near Fóu-p'ing-hién both east and west of the city. Our

specimen was obtained from the central part of a dike 40 feet, 12 meters, thick, which traverses gneiss 4 miles, 6.5 kilometers, west of Fóu-p'ing.

The aphanitic ground-mass is dull brown in color. In it are embedded medium-sized phenocrysts of pink orthoclase and plagioclase, glassy quartz and green hornblende. The feldspars are much the most prominent features of the rock. The ground-mass is a microcrystalline mass of quartz and feldspar granules, containing bits of hornblende, iron ores, and other minute accessories.

With the exception of quartz all the phenocrysts are extensively decayed. Both feldspars are thus replaced by saussurite to such a degree that the plagioclase is difficult to identify; it seems to range from oligoclase to andesine, in zonally built crystals. Scarcely any of the hornblende remains intact. It is now represented by perfect pseudomorphs, which consist largely of chlorite associated with epidote-zoisite, delessite, and calcite. The small grains of magnetite, titanite, and zircon are unaltered.

Aside from such katamorphic alterations as these, no changes have been observed. The rock has not been subjected to anamorphic processes nor even to effective stresses. Its undeformed condition, as well as its mineralogical contents, leads us to compare it with the porphyries along the T'ai-shan-ho and the similar dike which traverses the Ta-yang limestone near T'ang-hién. It is probably Post-Algonkian and not improbably Post-Carboniferous in age.

White garnet aplite, No. 69.—Small dikes and sheets of felsite accompany the granite porphyries which intrude the gneisses near T'ang-hién. This specimen was taken from a sheet 2 feet, 0.6 meter, thick, near the summit of a hill 2 miles, 3 kilometers, west of Chuang-li village.

Externally the rock is white, minutely flecked with brown, green, and red particles, which the microscope shows are dark epidote and garnet. The arrangement of these specks suggests a parallel structure and yet the rock is not in any sense schistose. The white aphanitic portion is composed of fine granules of quartz and alkali feldspar. The other minerals are unimportant in quantity and are arranged in discontinuous streaks. Small granules of garnet and epidote with parallel flakes of a pale pleochroic mica are the only common varieties present.

The faint parallel structure of the mass is an evidence of effective mechanical deformation. The existence of the garnets and parallel micas is additional proof that the felsite has been subjected to anamorphic conditions. From the intimate association between garnet and epidote we infer that it also developed under mass-static conditions in the deeper zone. These metamorphic features indicate that the rock is not younger than the gray granite porphyries of Algonkian age.

White epidote aplite, No. 70.—Similar to the last. Specimen from a dike 2 feet, 0.6 meter, thick, which appeared to be an apophysis from the gray granite porphyry (No. 68).

This specimen differs from the last chiefly in the absence of garnet and in the greater abundance of little blotches of dark epidote. The trace of gneissic banding is even more distinct than in the last case.

In the thin section one observes small distorted phenocrysts in the microgranular ground-mass of quartz and feldspar. They consist of quartz, orthoclase, and albite. Most of these phenocrysts have not been notably distorted during the slight metamorphism of which the matrix bears evidence; granulation appears to have occurred locally along their edges.

Granules of epidote and minute flakes of muscovite are distributed in indistinct parallel streaks. The epidotes often inclose a dark-brown mineral which is thought to be allanite. Rare grains of magnetite and brown ferruginous impurities complete the short list of accessories.

This aplite is a porphyritic felsite which has undergone slight deformation in the zone of anamorphism. The changes are comparable to those in the granite porphyries with which it is closely associated.

TA-YANG SERIES (ALGONKIAN).

The Ta-yang series is of late Algonkian age. The rocks are gray cherty limestones with thin members of shale and quartzite. Locally where folding has been intense the shales are schistose, but elsewhere the rocks are not more altered than the overlying Paleozoic terranes.

Rocks of Sedimentary Origin.

Carbonate Rocks.

Banded gray limestone, No. 88.—This is a typical example of the banded but chertless layers of the Ta-yang limestone. Specimen from the lower 1,000 feet, 300 meters, of the formation.

A dense clear-gray rock traversed by narrow wavy bands of dark-gray color. Under the microscope it appears to be composed entirely of small interlocking calcite grains. There are no fossils nor other peculiarities of structure. The layers of dark pigment which produce the banding in the hand-specimen existed before the rock crystallized. The crystals of calcite have simply absorbed them as they grew, and thus the bands pass through the crystals without the slightest deviation (Plate LVI, Fig. D).

SINIAN SYSTEM.

The Sinian (Cambro-Ordovician) system in Chï-li is so nearly identical with that in Shan-tung as not to require additional description. The only specimens in our collection came from a terrane which is believed to mark the base of the Cambrian in the vicinity of T'ang-hién.*

*For a discussion of the age of the rocks near Nan-t'ang-mei see p. 140, Part I.

Rocks of Sedimentary Origin.

Psephites.

Gray flint conglomerate, No. 73.—In the hills southwest of Nan-t'ang-meï a heavy bed of this hard conglomerate lies unconformably upon the Ta-yang limestone (Algonkian). It is composed chiefly of residual flints from the older rock.

The rock is a pale-brown quartzite filled with angular fragments of black, gray, and banded flint. It deserves the term "breccia," but "conglomerate" is preferred because it implies the sedimentary origin of the rock.

The quartzitic matrix consists of rather coarse rounded grains of quartz, and rarely feldspar, cemented together by microgranular silica identical with flint. The flinty pebbles have been enlarged by the deposition of such silica until their edges have been largely obliterated. The cement between the grains has thus become continuous with the flint bodies and at first glance the sand-grains seem to be inclosed in the flints instead of being subsequent in age (Plate LVI, Fig. C).

This hard rock has not been perceptibly deformed since it was deposited and, being entirely siliceous, it has not been katamorphically altered.

Psammites.

Dense white quartzite, No. 74.—This fine-grained pure quartzite lies conformably above the conglomerate just described. Its relation to younger terranes is not precisely known, however, for the soft shales which seem to lie above it have been extensively stripped off from the quartzite ledges.

A very pure quartzite of fine texture and gray-white color. On bedding planes it is stained greenish. Internally the microscope discloses small angular and subangular grains of quartz and subordinate feldspars. It is worthy of note that flint does not occur among these grains nor in the matrix of the conglomerate (73). The grains are embedded in an ample gray cement, which has the constitution of a siliceous shale, *i. e.*, a cryptocrystalline mass of quartz and kaolin flakes.

Like the last, this rock bears no marks of strain nor alteration.

Wu-t'ai district, Shan-si.

In the Wu-t'ai district we include the main range of the Wu-t'ai-shan and the adjacent valleys of the Hu-t'o-ho and its tributaries in Shan-si province (see atlas sheets). The most abundant rocks of this district are metamorphosed Algonkian sediments belonging to two distinct systems. Limited outcrops of the T'ai-shan (Archean) complex and larger areas of Sinian strata likewise occur. Of the Algonkian systems, one is highly metamorphosed (Wu-t'ai system), while the other is but weakly deformed (Hu-t'o system) and is in many places no more altered than the Paleozoic.

WU-T'AI SYSTEM.

The rocks of this system are referred to the early Algonkian. They comprise a great variety of mica schists and gneisses, garnet schists, chlorite schists, quartzites, marble, schistose conglomerates, arkoses, etc. Through these metamorphosed sediments igneous masses of several ages have been intruded, and some of them have since been metamorphosed. They include granite, augen-gneiss (probably Post-Wu-t'ai), hornblende schists, quartz porphyries, etc. Some of these dikes are older than the Hu-t'o series, while some are later and may even be Post-Paleozoic.

ROCKS OF SEDIMENTARY ORIGIN.

PSEPHITES.

Green schistose conglomerate, No. 97.—Layers of conglomerate are prominent in the greenish schists at several points in the Wu-t'ai range. The present specimen was taken from such a layer in the canyon below Wu-t'ai-shan village (Plate XVIII, stratum No. 30). This formation is regarded as the base of the Si-t'ai green schist group.

A thoroughly schistose greenish rock in which numerous pebbles of quartz, quartzite, and granite are embedded. The less refractory inclusions have been visibly elongated in the direction of cleavage, but some of the pure quartz pebbles retain their original forms.

The matrix is a heterogeneous mixture of particles, great and small, of quartz, feldspar, calcite, iron ores, and pale micas. The mica flakes are roughly parallel and the mass is traversed by many wavy shear-zones, all of which coincide with the schistosity. The visible grains of quartz and feldspar are often set in eye-spots avoided by the shear-zones, and are therefore to be regarded as sand-grains older than the schistosity. Other granules have been produced by the peripheral granulation of the pebbles under heavy stresses.

The cryptocrystalline brightly polarizing aggregate which forms the base of the ground-mass is composed largely of micaceous minerals such as sericite, kaolin, and chlorite. Some of this probably represents original clay material partly metamorphosed, but another portion is intimately associated with granulated edges of feldspars and is to be regarded as an anamorphic product of the alteration of that mineral.

The origin of the calcite bodies is not entirely clear. The mineral is not common in schists and is probably not produced in the zone of anamorphism. A part may have developed since the rock emerged from that zone, but the relations of many of the calcite bodies proves that they were present during the deformation of the mass. Many of them are inclosed in eye-spots which are avoided by the little shear-zones in the matrix. It is

are all heavily strained, many of them sliced and considerably granulated locally, and shear-planes traverse the mass at frequent intervals. The longer grains show a rude parallel arrangement, as if they had been rotated into a common plane. Part of the granulated material derived from the sand-grains has been recrystallized in the form of fresh quartz and orthoclase crystals. The greater part of the rock still consists, however, of unreduced, though distorted, sand-grains.

Black magnetite quartzite, No. 91.—The compass-needle is perturbed by this rock in the canyon of the T'ai-shan-ho about 4 miles, 6.5 kilometers, above Shï-tsui. The quartzite is interbedded with schists of the Shï-tsui series (Plate XVIII, stratum 19).

The quartzite is black, with narrow gray bands parallel to the stratification planes. The texture is fine. Quartz and magnetite are the only abundant components, and the variations in the relative abundance of these two minerals in different layers impart the banded appearance of the exteriors. The quartz grains form an interlocking mosaic without cement, while the iron ore occurs in cubic and octagonal crystals of variable size interspersed or even occluded in the quartz (Plate LVI, Fig. E). These features indicate that the rock is a ferruginous quartzite which has entirely recrystallized without becoming schistose. The conditions were probably those of mass-static anamorphism.

Subsequent changes are evidenced by the occurrence of irregular fissures filled with tertiary magnetite, associated locally with chlorite and siderite. These last minerals are characteristic of the belt of cementation, and the very existence of the fractures shows that the rock had emerged from the anamorphic zone previous to the production of these veins.

Micaceous graywacke, No. 84.—A phase of the schist-and-quartzite sequence in the lower part of the Shï-tsui series. Specimen collected near the top of a micaceous quartzite (Plate XVIII, stratum 4), 1.5 miles east of Shï-tsui.

The rock is purplish-gray in color with much black mica in certain layers. All the crystals are minute, but the specimen is not strongly coherent and the feel is sandy. The compact mosaic of small grains consists of quartz and various alkali feldspars. No schistose structure appears in the slide. In darker bands shreds of biotite with green hornblende and epidote are abundant. They exhibit no definite parallelism in their orientation.

Although this rock is part of a sedimentary sequence its clastic structure is no longer visible. The original constituents have recrystallized without the development of schistosity. Its composition suggests that it was formerly a fine-grained grit or pelite.

Gneissic graywacke, No. 92.—This resembles the last rather closely and, if the structure of the Shï-tsui section is synclinal, it may represent a recurrence of that very stratum. The specimen comes from quartzitic layers interbedded with schists about 4 miles, 6.5 kilometers, up the T'ai-shan-ho from Shï-tsui (Plate XVIII, stratum 20).

The rock has a pale pinkish color modified by black scales of mica on the cleavage planes. The texture is fine, as in the last variety. In composition the rock is closely similar to No. 84, but it has been metamorphosed. The original grains of quartz and feldspar have been reduced by mashing to a granular banded aggregate in which a few of the deformed sand-grains have still escaped complete granulation. Secondary flakes of muscovite and biotite lie in streaks parallel to the cleavage, except where interfered with by the remaining sand-grains. Abundant calcite bodies form a part of the mosaic. The ease with which this mineral recrystallizes enables it to adjust its forms readily to changing conditions during metamorphism. As it occurs in this rock, therefore, it exhibits no strain phenomena or other evidence of the anamorphism through which it has passed.

Gneissic arkose, No. 98.—Certain arkoses and arkose schists lie upon the conglomerate schists of the Si-t'ai group. Specimen collected 3 miles, 5 kilometers, south of Wu-t'ai-shan village from beds equivalent to the top of stratum 30 in Plate XVIII.

This is a gray massive rock with an obvious parallel structure, but not distinctly banded. The surfaces are dotted with glassy and red quartz and feldspar grains like phenocrysts in a porphyry. The internal constitution of the rock is similar to the ground-mass of the conglomerate (No. 97) and needs but little additional mention. The relatively coarse grains of quartz and alkali feldspar have been greatly deformed and through granulation have contributed largely to the formation of the schistose ground-mass. Here again the superior resistance of feldspar to deformation is exemplified; quartz is readily granulated, while feldspar often remains in eye-spots. The micas of the ground-mass are chiefly minute flakes of sericite with some chlorite.

Quartz-sericite schist, No. 99.—The transitional zone between the green schists and the arkoses of the Si-t'ai series comprises gray quartzose schists and gneisses which grade into the rocks both above and below without clear distinction. This specimen was found not far below the green schists, 2 miles, 3 kilometers, south of Wu-t'ai-shan village.

A pale greenish-gray rock with imperfect slaty cleavage. The surfaces have the silvery sheen of sericite, but most of the constituents are too minute to be seen with the unaided eye. The microscope shows that the

rock differs from the last described chiefly in having a greater proportion of quartz with less feldspar. Although numerous "augen" still inclose unreduced sand-grains, the body of the rock is thoroughly schistose. Quartz and feldspar granules in parallel bands are associated with minute sericite flakes. The ferruginous impurities in the original psammite have recrystallized in the form of magnetite. Judging from its composition the present schist represents an impure argillaceous quartzite which has been severely metamorphosed.

PELITES.

Gray phyllite, No. 101.—This slaty rock is one of the lowest recognized members of the Nan-t'ai series. It lies upon the jaspery ferruginous beds which mark the overthrust in the canyon of the T'ai-shan-ho,* south of Wu-t'ai-shan village.

A dark-gray slate which cleaves into thin parallel laminæ. It is composed largely of a dense argillaceous mass which has a pronounced schistose structure. The constituent minerals are chiefly sericite with micaceous hematite and granules of quartz. Parallel to the cleavage the rock is traversed by lighter bands of coarser texture, which contain quartz and calcite with flakes of greenish biotite. All of the minerals occur also in eye-spots, as if they were original constituents of the slate. Biotite, however, is a characteristic product of anamorphism and we are disposed to regard it as of secondary origin. It may have been developed under earlier mass-static conditions and subsequently deformed by differential stresses.

From the constitution of the phyllite we infer that it was formerly a calcareous shale.

Purplish biotite schist, No. 86.—This represents a metamorphosed shale in the quartzite-and-schist sequence east of the T'ai-shan-ho. It is a member of the Shï-tsui series (Plate XVIII, stratum 9).

A rather massive schist of purplish-gray color.

Thin disk-like knots of coarse black biotite are scattered sparsely over the cleavage planes, but otherwise the micas are too minute to be readily observed. The thoroughly schistose mass consists of parallel seams of quartz and feldspar granules with flakes of biotite and muscovite and abundant rectangular bits of magnetite. The micas are subordinate in quantity to the quartz, and they do not form interlaced seams except in the black knots referred to above.

The rock is evidently a schistose pelite, derived, perhaps, from a red ferruginous shale. Nothing remains of the original components except certain crushed lenses of quartz which may have been sand-grains. The argillaceous mass has recrystallized in parallel crystals adjusted to the

*Part I, p. 112.

stresses. Subsequent crystals of biotite and tourmaline have begun to grow across the schistose structure, but they are few and small.

Scapolite-staurolite schist, No. 158.—Our specimen of this schist was taken from a pebble in conglomerate (106 and 107) south of Fang-lan-chön, Shan-si. The conglomerate is believed to be of later Algonkian age (Hu-t'o), but the schist pebbles have their closest relatives among the intensely metamorphosed sediments of the Wu-t'ai series; and it is appropriate, therefore, to describe the rock as a member of that series. The schist resembles most closely certain members of the Shi-tsuï section.

A very fine-grained schist which cleaves with facility only along certain planes sheeted with biotite flakes. Under the microscope the body of the rock shows a thoroughly schistose structure; it is almost identical with that already described for No. 86. The schist is interrupted by porphyritic crystals of several minerals characteristic of the deep zone. Large flakes of biotite are interleaved with secondary quartz in the coarser laminæ of the rock. Ragged yellow staurolites are associated with them. Throughout the rock little prisms of tourmaline lie at all angles regardless of previous structures.

Scapolite* occurs in elliptical bodies distributed sparsely throughout the rock. The lenses have no definite boundaries, but are intimately associated with the biotitic ground-mass, while inclusions of magnetite, quartz, and tourmaline are so abundant as to obscure the scapolite itself in large measure. The age of the scapolite is somewhat doubtful. The elliptical form of the sections and the bulging of the schistose layers around them suggest original grains deformed under mass-mechanical conditions. On the other hand, the inclusions in the scapolite are part of the schistose matrix and lie in parallel lines. Among them are tourmaline and biotite—both anamorphic products. It seems more probable, therefore, that the scapolite is one of the latest minerals in the rock; that it grew *in situ* and occluded during the process the crystals it now contains.

This schist represents intense metamorphism of a pelite. Van Hise regards staurolite and tourmaline as typical minerals of rocks which have suffered the extremity of alteration in the zone of anamorphism. The fact that recognizable quartzites are associated with this schist in the Wu-t'ai series only adds to the weight of evidence that quartzite is wonderfully resistant to metamorphism.

Scapolite-biotite schist, No. 87.—This is only a peculiar phase of the schist last described. It is associated with garnet schist (Plate XVIII, stratum 7).

The rock is very similar to No. 86, except that the black biotitic disks are absent, and in their place we see many grayish spots of ovoid form—

* Although this mineral resembles orthoclase superficially, in this case it was identified by the uniaxial interference-figure and high birefringence.

all slightly elongated in a common direction. Under the microscope these spots appear to be grains of scapolite which have been rounded by granulation and elongated in the plane of schistosity.

They are filled with inclusions of magnetite, quartz, and tourmaline, and are therefore believed to be of later origin than the schistose mass in which the tourmaline grew.* Along irregular cracks the scapolite alters to micaceous material resembling kaolin. The pitted surface of the weathered schist indicates how rapidly the scapolite is dissolved when exposed to the air.

Garnet-staurolite schist, No. 95.—A thick mass of dark garnet schist separates the white marble of the Shang-ho-miau section from the body of augen-gneiss which lies south of it. It appears probable that the augen-gneiss is a metamorphosed intrusive in the Wu-t'ai system, and on this hypothesis the garnet schist may represent the contact phase of the sedimentary strata. Our specimen was taken in the lower layers of the schist adjacent to a dike of schistose greenstone.

A silky gray schist studded with small red garnets and larger, though much less conspicuous, staurolites. The cleavage is irregular and the laminæ are lumpy with the porphyritic crystals.

The rock is so thoroughly schistose that none of its original components may now be recognized. Much of it consists of a schistose mass of quartz and feldspar, with minute flakes of biotite, muscovite, and iron ores.

In this ground are embedded tertiary crystals of red garnet, biotite, staurolite, and tourmaline. The garnet is idiomorphic and includes many small bodies of iron oxides, etc. The very ragged crystals of staurolite are of much larger size, but are fewer in number.

A number of distinct episodes in the history of this rock may be deciphered from the thin section (Plate LVI, Fig. F). From the analogy of other garnet schists we infer that the original sedimentary rock was a pelite of complex chemical constitution. This original material has completely recrystallized during metamorphism; new minerals resulted, and all new structures were adjusted to the stresses. At a later time, while still in the zone of flowage, the rock developed crystals of heavy silicates such as biotite, garnet, and staurolite. They grew *in situ*, absorbing the earlier minerals of the schist as they did so. A recurrence of differential movements slightly deformed these porphyritic bodies. The garnets and biotites lie in eye-spots bounded by shear-zones, while the large ragged staurolites have been granulated and dragged out into streaky forms. A much later episode of alteration, this time in the katamorphic zone, permitted the formation of a little chlorite from biotite and garnet.

* A fuller description of the scapolite is given in the description of No. 158, p. 427.

CARBONATE ROCKS.

White marble, No. 96.—Two members of white marble occur in the Shang-ho-miau portion of the T'ai-shan-ho section. The lower one is interbedded with garnet schists, while the upper bed is thicker and uninterrupted by schists. Our specimen came from the upper layers of the lower marble (Plate XVIII, stratum 23).

A finely crystalline marble of gray-white color. Indistinct gray bands appear to mark the original bedding-planes. The rock consists almost entirely of interlocking crystals of a carbonate, which is probably calcite. The only accessory minerals are a few flakes of muscovite which are scattered at random through the mass.

According to the usual habit of such rocks, the original limestone did not become schistose when metamorphosed, but merely recrystallized into marble in which no evidence of strain or fracture may be seen.

Banded impure marble, No. 100.—Banded impure marbles of gray, brown, and reddish colors, containing seams of chert, jasper, and hematite, occur just above the fault-plane upon which the Nan-t'ai series overrides the white marble syncline on the west side of the T'ai-shan-ho. The marble is interbedded with layers of dark quartzite and slate (No. 101). The present specimen, collected 0.5 miles, 0.8 kilometers, up the ravine which comes in from the north, may be considered fairly representative of the limestone portion of the true Nan-t'ai.

The dark-gray and red portions of the rock are finely crystalline, but the wavy white bands are composed of coarser quartz and calcite. Little seams of steel-gray hematite occur in the quartzose layers.

The internal composition of the rock is so complex that the term "marble" is of doubtful appropriateness. The red bands are rich in hydrohematite dust, but otherwise resemble the gray layers. The latter consist of a fine mosaic of quartz, calcite, and feldspars (both orthoclase and plagioclase). All are abundant, and they are intimately mingled as in a clastic rock. The rounded forms of many of the strained quartzes and feldspars strongly suggest that they are clastic grains, not yet recrystallized, embedded in a crystalline ground-mass of calcite. In certain bands the carbonate has been replaced by cherty silica as described by Van Hise* from the Lake Superior iron formations.

The lighter bands are evidently in the nature of veins which have been formed by the deposition of quartz, calcite, and hematite from solutions. The pronounced strain-shadows and sliced crystals show that the veins themselves have been severely deformed.

*U. S. Geol. Surv. Monograph XLVII, A Treatise on Metamorphism, pp. 850–851.

Banded cherty marble, No. 102.—This represents merely another phase of the last, and it was obtained at the same outcrop.

Finely laminated brown and reddish bands alternate with white hematitic layers much as in No. 100. The darkest laminæ weather out in relief because of their siliceous composition; while the gray and red layers are more easily dissolved. As viewed in thin section these cherty and calcareous bands intergrade without demarkation. The whole rock has an obscure parallel structure which is emphasized by the streaks of iron-ore granules which give color to the dark layers. Much of this parallelism may be ascribed to stratification in the original limestone, but the deformation has also been a notable factor.

Pink and green amphibolite, No. 85.—This is a rock of unusual appearance which is associated with the lowest members of the Shï-tsui series southeast of the village of that name. Layers of considerable thickness are interbedded with biotite schist and lie beneath the quartzite on the east tributary of the T'ai-shan-ho (Fig. 20, stratum *b*). Its relations to the section, as well as its mineral composition, indicate that it is a metamorphosed limestone.

The attention of the geologist is at once attracted by the peculiar color of this amphibolite. Most of the rock is composed of light-green actinolite needles, but pink calcite is interspersed in many irregular blotches. The structure is massive, as in a marble, and neither banding nor cleavage is observable.

The little needles of actinolite are disposed in radiating bunches in a ground-mass of quartz and calcite, with subordinate feldspar. Near the centers of these rosettes biotite usually occurs in large ragged flakes (Plate LVII, Fig. A). The biotite flakes cut directly through the actinolite fibers after the manner of tertiary porphyritic* minerals developed under mass-static conditions. Many of the fibers have been absorbed without change during the growth of the biotite.

Gneissic amphibolite, No. 90.—A thick bed of this amphibolite is included in the schistose sediments in the canyon of the T'ai-shan-ho above Shï-tsui (Plate XVIII, stratum 15). In the field its relations are those of a conformably bedded member of the Shï-tsui series.

A faintly banded massive rock consisting of a light-gray ground-mass in which are set long prisms of blackish-green hornblende. This network of amphiboles bears little relation to the gneissic banding. The crystals are promiscuously oriented.

* Word used in the sense of megascopic crystals in an aphanitic schist (Van Hise: A Treatise on Metamorphism, p. 699.

Excluding the porphyritic hornblendes, the rock is a biotite gneiss in which the microscope reveals a granular mosaic of quartz and alkali feldspars. The small ragged flakes of biotite are parallel, but are not sufficiently abundant to form continuous seams. Accessory ilmenite, apatite, and zircon complete the list of minerals present. All of these constituents are probably secondary products of recrystallization in the anamorphic zone.

The large hornblende crystals traverse this matrix at random. Many are roughly parallel to the banding, but not a few cross it at high angles and include portions of the schistose bands (Plate LVII, Fig. B). Obviously the hornblendes have grown in the deep-seated zone since the gneissic structure was produced.

More recent katamorphic changes in this specimen have resulted in kaolinized feldspars, the local alteration of biotite to chlorite and epidote, and of hornblende to chlorite with a little calcite.

The origin of this amphibolite can not be declared with confidence, although its association with quartzite and pelite schist in the field leaves little doubt that it is a sedimentary rock. Amphibolites of closely similar character which have been derived from impure limestones are described by Emerson* from the metamorphosed Paleozoic sediments of New England. The change in such cases involves the loss of CO_2 and the silication of the bases. In order to produce the high percentage of quartz, feldspar, and hornblende it would seem necessary to have either a rock which was originally very impure or one from which a large part of the $CaCo_3$ has been removed, thus increasing the relative importance of the impurities. In either case a considerable decrease in the volume of the limestone would be expected.

Rocks of Igneous Origin.

The Wu-t'ai rocks are traversed by a few intrusions, of which some have been subsequently metamorphosed, while others are unaltered. The first class includes granitic batholiths and basic dikes; the second consists of quartz-and-feldspar porphyries. The granites and greenstones are probably of Algonkian age, but the porphyries are so little altered or deformed that we may well suppose them to be much younger.

Greenstones.

Under this convenient field name may be grouped the dark hornblendic derivatives of diabases, basalts, gabbros, diorites, etc. Our specimens are both recrystallized, but one is massive and the other is schistose. In the Wu-t'ai district they occur as thick black dikes traversing the folded Algonkian rocks.

*Emerson, B. K., Geol. of Old Hampshire Co., Mass., U. S. G. S. Mono. XXIX, pp. 300–306, pls. V and VI.

Massive greenstone, No. 94.—A dike of this rock 60 feet, 18 meters, thick cuts the garnet schists at Shang-ho-miau (Plate XVIII, stratum 22). At a short distance the appearance of the intrusion suggests a basalt dike of recent origin, but closer study shows that the rock is completely metamorphosed.

A greenish-black massive rock of fine texture. It is composed of interlaced fascicules of hornblende mingled with limpid quartz and feldspar. The latter, being transparent, exert little influence on the color of the mass. In the thin section a rude parallelism of the hornblendes is apparent, but the structure is not sufficiently prominent to induce schistosity.

Recrystallization under anamorphic conditions has been complete, leaving no traces of original structures or minerals. More recently changes have taken place in the zone of fracture, resulting in the formation of chlorite from the amphibole and of micaceous material in the feldspars. The irregular bodies of ilmenite and pyrite are not visibly altered.

Schistose greenstone, No. 89.—Like the last this greenstone occurs as a dike in the walls of the T'ai-shan-ho canyon. The intrusion has a thickness of about 30 feet, 9 meters, and rises vertically through mica schists of the Shï-tsui series, 2 miles, 3 kilometers, northwest of Shï-tsui. A vein of hornblende-feldspar pegmatite emanates from the dike as if it had been an original apophysis from it.

The rock resembles No. 94 so closely that a brief description of differences will suffice in this case. The specimen is distinctly schistose and the thin section shows that the hornblende crystals lie in thin parallel laminæ alternating with streaks composed of the quartz and feldspar. The iron ores are less abundant, but granules of epidote and sphene, not observed in No. 94, are present here. It seems not improbable that the streaks of granular titanite may be secondary alteration products of original ilmenite.

Acid Porphyries.

Gray rhyolite porphyry, No. 93.—A few small dikes of quartz porphyries cut the quartzites and schists about 4 miles, 6.5 kilometers, northwest of Shï-tsui. From their similarity to dikes elsewhere which have intruded the Sinian strata we infer that they are likewise of post-Sinian age.

Our specimen is extensively decayed. In the gray surfaces one may detect a few phenocrysts of quartz, pink feldspar, and rarely magnetite. The quartzes are prominently idiomorphic and the pyramidal terminations may be clearly seen with a hand-lens. Under the microscope the feldspathic phenocrysts appear to consist largely of a micropegmatitic intergrowth of quartz and alkali feldspar. All of these crystals are bounded by opaque reaction rims and many are deeply corroded.

The aphanitic ground-mass is probably feldspathic, for it is now altered completely to grayish kaolinitic products sprinkled with specks of magnetite. Indefinite round blotches are suggestive of spherulites, but there are no other structures characteristic of glassy rhyolites.

Although greatly altered by weathering this porphyry shows no marks of strain or distortion. It has evidently been intruded after the last epoch of compressive deformation of the crust in the Wu-t'ai region. The folding of the Sinian and Carboniferous strata probably occurred in the Mesozoic, and the porphyries, which do not record the folding, may be regarded as even younger.

Rocks of Doubtful Origin.

Two gneisses of uncertain origin are included in this division. They are closely associated with the Wu-t'ai rocks, but are not known to be of the same age.

Gneisses.

Biotitic augen-gneiss, No. 83.—The gray augen-gneiss was observed at two points along the T'ai-shan-ho, and in both situations forms a homogeneous body of broad extent. The specimen was obtained from the tributary valley, 4 miles, 6.5 kilometers, south of Shï-tsui (Fig. 20, *g*), but identical fragments might easily have been found above Shï-tsui (Plate XVIII, stratum 21). The available evidence indicates that the gneiss is a metamorphosed granitic intrusive.

A black-and-white gneiss dotted with lenses of pink feldspar. The seams of biotite are notably wavy and reticulate, and the cleavage is imperfect.

The augen-spots are occupied by alkali feldspars (orthoclase and oligoclase) and more rarely by quartz. The quartz bodies are granulated and have been deformed into lenticular shapes. The feldspars, some of which are Carlsbad twins, show strains, but have preserved their integrity to a much greater degree. About their edges they have been granulated, and the resulting debris, mingled with the quartz of the matrix, has been largely recrystallized. Internally microcline grating has been developed in shapeless blotches. The microcline is always free from the inclusions of epidote, zoisite, and mica, which the orthoclase contains. The fact indicates that the microcline is the recrystallized product of the other feldspar.

The mass in which the numerous augen are inclosed is a typical biotite gneiss. Quartz, orthoclase, and albite form ill-defined granular seams separated by short wisps of biotite flakes. These wisps bend out around the eye-spots and envelop them. Titanite and calcite occur sparingly as constituents of this gneiss, forming irregular crystals like the

quartz and feldspar. The abundant epidote associated with the biotite is probably an alteration product of that mineral, as is the chlorite.

Two hypotheses concerning the origin of this rock appear tenable: (*a*) that it is a metamorphosed graywacke, and (*b*) that it was a porphyritic granite. If derived from the graywacke the existence of calcite as an integral part of the gneiss may be explained. The mineral occurs in compact allotriomorphic crystals which seem to have been formed at the same time with the quartz and feldspar. The explanation does not agree well, however, with the field occurrence of the rock. It is difficult to conceive of an arkose formation so thick and so uniform in constitution that, although it lies highly inclined and has an exposure 4 miles, 6.5 kilometers, broad, no considerable variations either in texture or in composition could be detected. We should confidently expect to find local beds of quartzite, conglomerate, or shale in an arkose of such enormous thickness. The second explanation fails to account satisfactorily for the calcite, but as it agrees with the other facts it is regarded as more probable than the other. If we suppose that the augen-gneiss is an ancient granite either intruded into the Wu-t'ai rocks or overthrust upon them from below, the uniform character and great extent of the rock may be explained. The twinned feldspars in the augen may be regarded as porphyritic crystals, as yet not destroyed by metamorphism, which has given the mass its gneissic structure.

Chlorite-muscovite gneiss, No. 103.—This specimen was taken from the top of Peï-t'ai, the highest peak of the Wu-t'ai range. The summit of the mountain consists of the gneiss, but in the adjacent slopes mica schists appear. The relations between the two are unknown.

Our weathered specimen is a mottled reddish-gray rock indistinctly streaked with dull green. It is neither banded nor readily cleavable, and yet a trace of parallel structure is observable especially in larger masses. The texture is granitic and moderately fine. Under the microscope the rock is separable into two kinds of material: (*a*) rounded or subangular bodies of feldspar and less quartz, and (*b*) the schistose material which binds them together and incloses the small accessory crystals of other minerals.

The feldspars are much obscured by inclusions of muscovite, zoisite, etc., but the range of extinction angles indicates that orthoclase, albite, and labradorite are present. Most of the feldspar grains are enveloped in wavy seams of the schistose portion and thus form eye-spots. Some of them have been broken and the fragments dragged apart only to be recemented by secondary feldspar and muscovite. The less numerous quartz bodies are granular lentils which have doubtless been produced through the crushing of single quartz grains. The occurrence coincides with that of the feldspar.

phosed than the majority of the Wu-t'ai rocks. The schistose conglomerates (97) of the Si-t'ai series resemble the present rock in some particulars, but even they have been more severely metamorphosed and are probably much older.

Specimens from the spur at a point 2.25 miles, 3.6 kilometers, south of the village of Fang-lan-chön, Shan-si.

This is an arkose or graywacke of coarse grain, which contains pebbles of various sizes up to 8 inches in length. The majority of the pebbles are of quartzite, but the list also includes gray phyllite, chlorite schist, scapolitic biotite schist (158), and vein quartz. The matrix in which these pebbles are embedded has a greenish-gray color, modified by the presence of numerous bits of pink feldspar. The rock is indistinctly banded and the pebbles lie with their broad sides parallel to the bands. Although the evidence of mechanical deformation is plain, true schistosity is only incipient.

The pebble in No. 106 is a pure quartzite which consists almost wholly of rounded grains of clear quartz, cemented with the same material. The grains show strain-shadows, but they have not been fractured, and even the cement has been only slightly granulated. In No. 107 the only large pebble is a soft, dull-gray, sericite slate or phyllite (slide 107–*c*), of which the only plainly visible components are a few grains of quartz.

The matrix of the conglomerate is an indurated arkose which shows only traces of schistosity. In No. 107 it consists of rounded and subangular grains of quartz and feldspar distributed rather sparsely in a ground-mass composed of minute particles of colorless micaceous minerals, quartz, and iron oxides. The quartz and feldspar grains are strained and occasionally fractured; and, at certain points of contact, granulation has occurred. No. 106 was more severely metamorphosed. The matrix has a distinct though poorly developed schistose structure. Several of the larger sand-grains are followed and preceded in the line of schistosity by granulated areas, but in general these "eye-spots" are not well defined. In some of the mashed areas small secondary crystals of microcline have begun to appear. Magnetite occurs in angular grains, many of which have changed to pseudomorphs of martite. Earthy hematite also fills many of the fractures in the sand-grains and occurs with limonite as a reddish-brown pigment in the microscopic shear-zones. Locally the ground-mass contains clusters of minute purplish-brown tourmaline laths, which are evidently of secondary origin.

PSAMMITES.

Impure sandstone, No. 104.—Hard quartzitic sandstones of purple, pink, and gray colors lie upon slates and beneath conglomerates in the north end of the ridge east of Tung-yü. The relations suggest that the series is

overturned and that the sandstone is really younger than the conglomerate. The sandstone appears to be a part of the Tóu-ts'un series. This specimen was obtained from one of the pinkish bands in the formation (Fig. 23, *a*).

A hard but slightly friable pink sandstone of fine texture. The color is considerably modified by opaque white and yellow materials among the quartz grains; these are probably decayed feldspars with more or less limonite. Scales of white mica are freely distributed through the rock.

Carbonate Rocks.

Red dolomite, No. 105.—This is a member of the local red shales and limestones which form a small but conspicuous part of the Tung-yü limestones in the ridge 4 miles, 6.5 kilometers, SW. of Wu-t'ai-hién (Fig. 23, *g*).

A dense light-red limestone which fractures irregularly. The thin section reveals a finely crystalline mass of carbonate which is very slowly attacked by HCl and may therefore be regarded as dolomite. The red color of the rock is due to the presence of hydrohematite dust, which clouds the carbonate. The distribution of this dust was probably effected before the mass crystallized, for the bands of lighter and darker color pass through the crystals without deviation (see No. 88, Plate LVI, Fig. D).

SINIAN SYSTEM.

The Sinian or Cambro-Ordovician series consists chiefly of limestone with shales and occasional sandstones, all of which are essentially unaltered. Many of the limestones are oolitic or conglomeratic, like the rocks of that character which have already been described from central Shan-tung. No igneous rocks have been found associated with this system in Shan-si.

Rocks of Sedimentary Origin.

Hematitic sandstone, No. 108.—A local iron-bearing phase of the sandy basal layer of the Man-t'o red shales (Cambrian). This member lies directly and unconformably upon the limestones of the Hu-t'o series (Algonkian). Specimen from the basal Cambrian contact, 7 miles, 11 kilometers, southeast of Tóu-ts'un, Shan-si.

This sandstone is so completely cemented by hematite that it has the external aspect of pure iron ore; although the granular texture of the sandstone is visible, the quartz itself is not. The sand-grains are composed of quartz and are for the most part well rounded. They are completely cemented with crystalline hematite. Many of the original grains were peripherally enlarged with quartz prior to the deposition of the hematite; such enlargements tended to produce crystal shapes, and hence usually increased the angularity of the fragments.

Some of the sand-grains show undulatory extinction, while a few of the quartzes have been fractured and the breaks have been subsequently filled with hematite. Considering the fact that the strata lie in a sharply overturned and overthrust fold, these marks of distortion are extremely inconspicuous.

TS'IN-LING DISTRICT.

This district is limited to a narrow strip extending southward across the Ts'in-ling mountains from Chou-chï-hién to the southern boundary of the large granitic intrusion which forms the axial portion of the range. The rest of the southern slope of the Ts'in-ling range will be discussed in connection with the Han river district. The rocks in this area are for the most part sedimentary in origin and either highly metamorphosed or only slightly altered. Large intrusions of granite and occasional dikes of other igneous rocks are associated with them.

Doubtless more than one series of rocks is represented in this district. One large group carries impure coaly layers and bears such a close resemblance to the known Paleozoic strata in the valley of the Han, that we regard the two series as approximately equivalent. The other has every appearance of being much older; it consists largely of green and gray chloritic schists which resemble certain phases of the Wu-t'ai system in Shan-si.

HEI-SHUI SYSTEM (PALEOZOIC?).

These rocks are mostly metamorphosed limestone and slates, with quartzites and occasional layers of conglomerate. The strata are highly folded and are in some places schistose. Granites of later age cut through them in various places.

Rocks of Sedimentary Origin.

Olive-green slate, No. 111.—The green slate is one phase of the series of quartzites, slates, and siliceous limestones which is characteristic of the higher mountains just north of the Ts'in-ling divide.

Specimen collected in the canyon 2.25 miles, 3.6 kilometers, below Chang-k'ou-shï.

A dense, light olive-colored slate in which no mineral grains are visible to the unaided eye. Slaty cleavage is rather imperfectly developed at an angle of about 30 degrees to the alternate darker and lighter bands which indicate the original bedding. Most of the slaty planes are striated as if they had been the loci of slipping movements. The rock also shows a subordinate tendency to cleave along the bedding-planes.

The microscope shows that the rock is composed of an aggregation of exceedingly minute grains of quartz, with clay-like materials, among which it is possible to identify with reasonable certainty chlorite, sericite, kaolin,

and iron oxides. In addition there are a few scattered bits of tourmaline, small quartz grains, and here and there a zircon, all of which are probably of clastic origin. The little tourmaline prisms are too ragged and worn to warrant the supposition that they are secondary crystals. The mass is thickly sprinkled with minute blackish flakes and formless shreds of carbonaceous material.

This was formerly a siliceous shale in which slaty cleavage has been imperfectly developed. Most of the constituents appear to be those of the original mud, but the micaceous minerals and the quartz are probably in the early stages of recrystallization.

Pyritic black slate, No. 109.—This is a local member of the partially metamorphosed Hei-shui system of the Ts'in-ling mountains, and was found exposed in the canyon below and above Siau-wang-tién.

Specimen collected 2.25 miles, 3.6 kilometers, downstream from Chang-k'ou-shï, May 2, 1904.

A dense steel-black rock through which are scattered numerous small bits and roundish bodies of pyrite (or marcasite) which range up to a centimeter in diameter. The cleavage is not as clean and even as it is in most slates, and the faces are therefore rough.

In many ways the rock is comparable to No. 133, but represents a more advanced stage in the progress of anamorphism. The crypto-crystalline ground-mass of quartz and graphitic matter contains abundant minute sericite flakes which have a distinctly parallel arrangement.

Interspersed with this ground-mass there are a few bodies of pyrite inclosed sometimes in quartz, more frequently in zoisite, and sometimes in both. The areas are usually ellipsoidal and the outlines are ill-defined. In addition to these nodules the pyrite occurs as minute specks scattered through the rock. The zoisite also occurs separately in small irregular bodies or in larger nebulous clusters. The origin of these nodules is not evident at first sight, but the association of a lime-silicate with pyrite and organic matter, in a rock which may easily have been fossiliferous, suggests that the spots have been produced by changes induced by the presence of shell-bearing organisms in the original mud. The carbon and the sulphur would be supplied by the decay of the organic matter, while the lime, iron, and alumina could be derived from the shells and the mud itself.

Rocks of Igneous Origin.

Igneous rocks other than the Post-Carboniferous granites are rare in the Ts'in-ling district. In fact the only other intrusions noted are some small dikes of gray felsitic rock and schistose greenstone, which cut the supposed Pre-Cambrian schists and limestones at the mouth of the canyon of the Hei-shui-ho. Unfortunately we have no specimens of these rocks.

Granites.

The granites of the Ts'in-ling mountains were first noted and briefly described by von Richthofen.* Since then other descriptions, based upon microscopic study of the rocks, have been published.† All are brief and generalized, but they refer to localities both east and west of our route and hence give an idea as to the uniformity and distribution of the granites.

Hornblende-biotite granite, No. 113.—This granite is characteristic of the main divide of the Ts'in-ling range. It has been intruded into metamorphosed sedimentary rocks, which are almost certainly late Paleozoic in age. Specimen obtained near the contact between the granite and the older rocks on the north side of the Ts'in-ling divide, near Wön-kung-miau, Shen-si.

By the influence of the granite intrusion the dark slates near the contact have been changed into medium-grained black mica schists. The junction is sharply marked by an irregular line across which occasional small dikes of granite extend into the country rock. A specimen (No. 112) collected at the very contact shows interesting variations in both granite and schist.

Between the spotted granite and the contact there is a layer, a little more than a centimeter thick, which is nearly white and is evidently poor in ferro-magnesian minerals. The microscope reveals quartz and orthoclase in about equal proportions, with a little biotite.

This passes abruptly into a rock of finer grain composed of quartz with feldspar and abundant shreds and short bits of red-brown biotite. Although the micas have a rude parallel arrangement the rock is not banded. Here and there much larger crystals of orthoclase and microcline are embedded in the schist. They are always filled with inclusions of biotite. At other points in the schist, muscovite becomes as abundant as biotite; or still elsewhere we may have an abundance of small black particles of magnetite.

The Ts'in-ling granite is a speckled black-and-white rock of medium grain. It is composed largely of white and glassy feldspars, clear quartz, and blackish hornblende and mica. A few of the feldspars are much larger than any of the others, and yet the rock has not the appearance of a porphyry, because the phenocrysts contain abundant inclusions of smaller crystals which interrupt the cleavage faces and make them much less conspicuous.

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*Von Richthofen: China, vol. II, p. 570.

†Steuer: Mittheilungen über Gesteine aus dem Chinesischen Provinzen Kansu, Schensi, Hupe, und Honan. (Neues Jahrbuch für Min., Geol., und Pal., X, pp. 477–494.)

Koch: Report on Rocks collected by Lóczy in Asia (Wissenschaftliche Ergebnisse der Reise des Grafen Béla Széchenyi in Ost-Asien, III).

About three-quarters of the rock is composed of quartz and alkali feldspars. The darker minerals are biotite and hornblende in about equal amounts, with smaller quantities of titanite, iron ores, etc. There are also the usual little grains and prisms of zircon, apatite, and rutile.

The quartz appears in rather large irregular crystals which have very few inclusions aside from a few zircons.

The feldspars consist of orthoclase and microcline with a subordinate amount of plagioclase. The latter is mostly oligoclase, but some of the crystals show a zonal structure and appear to consist of nuclei which have a composition approximate to labradorite, surrounded by concentric shells which are more sodic in composition. The plagioclases contain many secondary inclusions of sericite, grains of epidote and zoisite, and possibly kaolin. Certain irregular plagioclases show a micropegmatitic intergrowth with quartz, indicating that the two minerals were contemporaneous in crystallization.

In general the ferro-magnesian minerals are closely grouped in separate clusters. The hornblende occurs in fresh irregular crystals which are closely packed together with the biotite. The pleochroism varies in general from pale greenish-yellow to light emerald-green and dark olive-green. Inclusions in the hornblende are neither numerous nor distinctive. Along its edges and cleavage cracks the mineral has undergone alteration into chlorite and yellowish fibrous aggregates, with epidote and probably other minerals. Many edges, however, show almost no alteration.

The large scales of biotite, although usually irregular, are sometimes decidedly hexagonal in outline. The color is a rich brown, but without any reddish tinge. Inclusions of apatite, iron ores, and rutile are abundant and there are also little zircons which are surrounded by dark halos. The process of alteration of the biotite to chlorite is fairly well advanced, and is accompanied by the formation of some epidote. In some of the flakes the edges and cracks have been bleached to a brownish-yellow color, probably by the removal of some of the iron.

Of the rarer minerals represented in the Ts'in-ling granite, apatite is found in small lath-shaped prisms, some of which have a pale bluish-green color while others have brownish centers. As usual the apatite was one of the first minerals to crystallize. Zircon is rather abundant in minute grains and regular prisms. Rutile occurs in a similar fashion, but is rare.

The rock is a typical biotite-hornblende granite, which is but little metamorphosed. Considerable evidence of mechanical deformation is shown by the quartzes, *i. e.*, strain-shadows and minute fracture-zones are prominent throughout the rock. Along contacts certain crystals have been granulated and the material partially recrystallized into a quartz mosaic.

In some of the feldspars bent lamellæ are also visible. It has evidently not been far below the zone of katamorphism. All of the secondary minerals, with the exception of microcline, are characteristic of that zone. Most of the potash feldspars show the microcline twinning. The crystals which possess this feature are but little decayed and are almost free from inclusions.

HAN RIVER DISTRICT.

This includes most of the drainage basin of the Han-kiang in the southeastern portion of Shen-si province. We limit it on the north, however, at the southern boundary of the axial intrusive granite of the central Ts'in-ling mountains.

The rocks which we saw in this region are metamorphosed sedimentary strata, all of which probably belong to the Han system (Paleozoic and Triassic?), and occasional igneous rocks which have been intruded into them.

HAN SYSTEM.

The Han system consists of sedimentary rocks which have been more or less severely metamorphosed. They are equivalent to the Paleozoic and Mesozoic rocks which are exhibited in relatively unaltered condition in the gorges of the Yang-tzï.*

ROCKS OF SEDIMENTARY ORIGIN.

PSEPHITES.

Conglomerate schist, No. 134.—This conglomerate occurs in the slaty anthracite-bearing series in the valley of the Nan-kiang in southern Shen-si. Its probable age is discussed on p. 302. Specimen collected near the pass 2.25 miles, 3.6 kilometers, NNW. of Tsöng-kia-pa.

Petrographic character.—A pale greenish-gray schist in which are embedded pebbles of quartz and probably limestone, ranging up to several centimeters in diameter. The cleavage, being controlled by the contours of the pebbles, is irregular and lumpy. The pebbles have been severely compressed, so that they now lie flattened and elongated in the plane of schistosity. The relation of this plane to the original bedding is not known.

The schistose structure of the rock is well brought out in the thin section: everything is elongated in the plane of schistosity. The pebbles are mostly lenticular, and the matrix, although very fine-grained, is highly micaceous.

The ground-mass of the conglomerate consists of finely granular quartz and feldspar, with flakes of chlorite and sericite. The quartz and sericite, intimately mingled, lie in long irregular streaks associated with curving

* See Yang-tzï gorge district, p. 465.

parallel wisps of chlorite. In this dense ground-mass small lath-shaped prisms of pleochroic brown tourmaline, with an occasional zircon, are scattered without order. The zircons affect the schistosity of the mass as original sand-grains, but the tourmalines cut through the layers at all angles and without disturbing the micaceous bands; they are doubtless secondary minerals which have grown *in situ*. The abundant cloudy granules scattered about appear to be epidote and zoisite, which have probably arisen from alterations in the feldspars.

The pebbles are of all sizes from several inches in diameter down to mere sand-grains. The majority are composed of quartz, but slate and bits of feldspar are also common. In addition there are bodies of calcite, some of which probably represent limestone pebbles; smaller bits of calcite occur among the products of decay of the feldspars.

Under the microscope the pebbles show plainly the effects of the severe pressure to which the rock has been subjected. Many of the quartz bodies have been partly or wholly reduced to granular lenses around which the chlorite ground-mass bends. In case any of the original body remains, it is usually followed and preceded by granulated trails of quartz, forming the corners of the "eye-spots." During the crushing the granulated quartz and the chloritic matrix have become intimately mingled, so that the edges of the pebbles have a frayed and ragged appearance. The limestone fragments, if such they were, have completely recrystallized into coarse-grained calcite in which the cleavage and twinning planes, as well as the longer axes of the pebbles, lie at only moderate angles to the plane of schistosity.

Psammites.

Green gneissic quartzite, No. 122.—The greenish gneiss is a phase of the schists referred to the Kui-chóu formation (Triassic?) in the canyon above Shï-ts'üan-hién. Specimen collected on the south bank of the Han river, at the sharp bend 2.5 miles, 4 kilometers, above Shï-ts'üan-hién.

This is a light silvery-green rock, finely and evenly laminated, but with cleavage not well marked; there is a tendency to break across the laminæ rather than parallel to them. The rock is very fine-grained, and the surface has a silvery sheen due to the presence of minute sericite flakes. The constituent minerals are largely of minutely granular quartz with some feldspar. The crystals are strained, as indicated by the undulatory extinction between crossed nicols, and there is a notable parallel arrangement of the granules. At somewhat regular closely spaced intervals the highly quartzose bands are separated by others which are rich in sericite, chlorite, zoisite, and epidote, with a little biotite. The minute flakes of the micas lie with their axes roughly parallel, thus forming long seams and laminæ.

The other minerals are scattered through these dark bands in grains and small clusters. The iron ore which is present is frequently surrounded by whitish films of leucoxene and is probably ilmenite. Here and there one sees roundish or lens-shaped bodies of badly decayed feldspar associated with much epidote, zoisite, and fresh granular feldspar.

During the severe dynamic metamorphism, of which this rock bears the marks, very few of its original components have escaped alteration. The strained condition of the grains of quartz and the arrangement of them in elongated stringers indicate that the ground-mass has been produced by the granulation of particles which were originally larger. This comminution of the quartz has probably been accompanied by recrystallization of a portion of the material, especially the clayey constituents, resulting in the micas and certain fresh limpid quartz and feldspar grains. A few large grains, mostly feldspars, were only partially destroyed by granulation: in the zone of katamorphism they have been changed in part to epidote, zoisite, and calcite.

The composition of this metamorphosed impure quartzite strongly suggests the unaltered quartzite, No. 144, which was found on the Ta-ning-ho. The former might easily have been derived from a rock similar to the latter by a moderate amount of mechanical deformation.

Black quartzite gneiss, No. 114.—The magnetic quartzite is a local member in the series of black limestones, slates, and gray schists, which are crossed by the Han river, in the canyon just above Shï-ts'üan-hién. It is probably a portion of the Wu-shan anthracite-bearing formation, which is of Carboniferous age. Specimen obtained in ravine 2 miles, 3 kilometers, south of the city.

A blackish-gray magnetic rock irregularly banded with white laminæ. The darker bands are rich in micas and magnetite, while the others consist almost entirely of quartz. The cleavage is good along the micaceous zones, but not throughout the rock. Although the texture of the quartzite is fine, yet it is visibly granular, and the flat faces along the cleavage planes are spangled with white and dark micas.

The light bands consist of medium-grained quartz crystals forming an interlocking mosaic. Through the quartz are scattered irregular aggregates of a carbonate, the crystals of which are cloudy and exhibit in most cases neither twinning nor cleavage; this mineral is probably dolomite. In the same zones with the quartz and dolomite there are scattered flakes of muscovite, with grains of magnetite and apatite. Such cracks as occur are generally filled with minute flakes of mica.

The dark bands consist largely of quartz of finer texture than that of the lighter bands. This quartzose field is thickly dotted with magnetite

and micas. The micas are biotite and muscovite, with a little chlorite, all of them scattered as separate flakes with their axes approximately parallel; these flakes, it will be observed, are not interlaced with one another in the form of continuous seams, as in most of the schists. The chlorite is an alteration product after the biotite. The abundant grains of magnetite, which give the rock its color and magnetic powers, occur either singly or in irregular clusters, sometimes associated with a little pyrite. Many of them are more or less perfect octohedra. Grains of epidote, needles of rutile, and laths of apatite are present as rather common accessory minerals.

It is probable that the minerals mentioned above are all of secondary origin, at least in the sense that they have been recrystallized under the conditions which prevail in the zone of anamorphism. From the presence of some aggregates of crystalline carbonates and quartz with grains of epidote, it is suspected that among the original minerals of the rock were certain complex silicates, such as feldspars, which by their decay produced these simpler compounds.

Gneissic graywacke, No. 132.—The brownish graywacke is a member of the Han system which is dominant along the road from Pa-li-kuan to Pa-kua-miau in southern Shen-si. It appears to lie above the black slates and is probably a part of the K'ui-chóu schists. Specimen collected 2 miles, 3 kilometers, north of the village of Pa-kua-miau.

A very fine-grained green-gray rock streaked with slender lines of reddish-brown color. The rock is not truly laminated, but fractures unevenly, having what has been termed "linear-parallel cleavage."*

The minutely gneissic structure is very prominent in the thin section, the lighter bands containing quartz and feldspar with epidote, while the darker layers contain a large percentage of biotite, chlorite and iron oxides, with certain less numerous accessory minerals. All of the minerals show a well-marked parallel orientation. At irregular intervals one sees larger bodies of quartz and feldspar which were probably sand-grains not yet reduced in the process of metamorphism. They are often set in "eye-spots" the corners of which are occupied by granulated material derived from the grains. The mica bands bend out around these porphyritic grains (Plate LVII, Fig. C). The biotite is present in the form of small dark-brown flakes, with which are associated minute scales of chlorite and granules of epidote and zoisite. All of these minerals are of secondary origin and the micas are distinctly oriented with reference to the schistosity. Small grains and scales of hematite, with little prisms of apatite, are scattered promiscuously through the rock. The section also reveals

*Leith, C. K., Rock Cleavage: U. S. Geol. Surv. Bull. 239, Plate I.

three or four very small garnets, none of which are noticeable in the hand-specimen.

This specimen has the composition of a fine-grained graywacke which has been subjected to considerable metamorphism in the deep-seated zone. The granulation of the large sand-grains is obvious and it must be supposed that much of the ground-mass has suffered in the same process. It is also evident, however, that the present constitution of the rock is due principally to the recrystallization of the comminuted material; during this process the fresh feldspars and quartz, the parallel micas, and other secondary minerals were developed.

PELITES.

Pyritic black slate, No. 138.—A prominent member in the anthracite coal-measures (Wu-shan) on the Nan-kiang in southern Shen-si. The series is exposed for several miles south of the village of Ku-niu-tu, and the present specimen was collected 2 miles, 3 kilometers, south of that village.

This is a hard, dense, bluish-black rock in which slaty cleavage is poorly developed. Although it breaks at rather distant intervals along parallel planes, it fractures much more often conchoidally.

In the thin section this black argillite is seen to be exceedingly fine-grained. Quartz and dark carbonaceous materials compose most of the mass, with a very few small sand-grains scattered at random. There seems to be no definite orientation among the minute flakes of kaolin, and there is no evidence of noteworthy progress in the recrystallization of the original shale. In addition to the minute grains of pyrite visible on the surface there are obscure blotches of a grayish substance which is not recognized.

Throughout the slide many microscopic shear-zones are seen; some of them are short and evidently only incipient, while others traverse the entire slide. These shear-zones are apparently the only visible evidence of mechanical deformation. Their general trend is not parallel to the rather faint lines which are indicative of slaty cleavage.

Black siliceous argillite, No. 133.—This is the coal-bearing argillite which is exposed 2 miles, 3 kilometers, north of Tsöng-kia-pa. It is associated in that locality with a metamorphosed conglomerate (No. 134).

A dense, aphanitic, coal-black argillite, which tends to fracture conchoidally rather than with true slaty cleavage. As seen in the thin section, the rock consists of uniformly and very minutely crystalline quartz and finely divided graphitic matter. The black pigment is not evenly distributed, but forms an obscure complex of wavy bands which give the slide a mottled appearance. In this slide there are no porphyritic grains nor any micaceous constituents worth mentioning.

The rock shows little evidence of metamorphism, except that the quartz may be recrystallized. No secondary minerals can be distinguished, nor are there any microscopic folds or thrusts. A few fractures which cut the rock in several directions have been healed with fresh quartz.

Black clay slate, No. 139.—This is a characteristic but thin member of the middle Paleozoic shales on the head-waters of the Nan-kiang in southern Shen-si. The entire formation is evidently the equivalent of the Sin-t'an shales of the Yang-tzï valley. The specimen comes from the gorge of the Nan-kiang 5 miles, 8 kilometers, south of the town of Chön-p'ing-hién.

A soft, coal-black clay slate in which the cleavage is well developed, but somewhat irregular, *i. e.*, the rock splits up into plates of uneven thickness and with somewhat rough surfaces. The only visible constituents of the slate are certain small bodies of pyrite and other minute grains which are not identifiable in the hand-specimen. On account of the high percentage of coaly material which this slate contains, even the thin section appears almost black; and other components are rarely recognizable. Here and there are scattered minute bits of calcite and quartz, and occasional flakes of a colorless mica, too minute to be identified. Only a suggestion of parallel arrangement can be noted with regard to the constituents of the rock, and it is evident that the recrystallization of the clay has only begun.

It is highly improbable that the slaty cleavage of the rock is due to this trace of schistose arrangement of the minerals, which is so inconspicuous a feature. It is evident that we have here an example of fracture cleavage as defined by Leith.*

Crumpled black slate, No. 131.—The crenulated black slate is a local phase of the Wu-shan coal-bearing slates on the Han river above Hing-an-fu. Good exposures occur near Siau-tau-ho, and our specimen came from an outcrop near the coal-dump on the north bank of the Han near that village.

A blackish aphanitic slate which has been deformed along two planes at a large angle to each other in such a way as to develop countless little parallel folds or crenulations. This gives the rock a striated appearance which is unusual and striking; the cleavage is of the type described by Leith† as "intermediate between plane-parallel and linear-parallel cleavages." The only visible minerals are a few oxidized grains of magnetite.

The rock consists mainly of fine-grained quartz, the usual graphitic matter and minute micaceous flakes (kaolin?), the orientation of which corresponds to the schistosity in all its vagaries. The only other mineral which is not directly connected with the shear-zones seems to be tourmaline, which is scattered in small prisms.

*Leith, C. K., Rock Cleavage, U. S. Geol. Surv. Bull. 239, p. 119.

†*Ibid.*, Plate I.

The rock has been folded and sheared in the greatest minuteness. In the thin section the parallel folds and overthrusts are made conspicuous by the fact that the black graphite is concentrated along these lines (Plate LVII, Fig. E). Wherever the folds have been actually ruptured the breaks have been healed by the deposition of secondary quartz, and in these same areas other minerals, such as chlorite, sericite, and micaceous hematite have also appeared. Original sand-grains of quartz have been fractured, sliced, or otherwise deformed. Magnetite, however, seems to have resisted the crushing better than the quartz and usually occupies eye-spots, the corners of which are filled with secondary crystals of the latter mineral.

Green nodular slate, No. 141.—The hard green slates are best exposed in the region of numerous landslides and gabbro intrusions south of Pai-kiu-hia. The formation is the equivalent of the green Sin-t'an shales of the Yang-tzï district. Specimen taken from landslide debris 3 miles, 5 kilometers, south of Pai-kiu-hia. It probably came from the broad contact zone bordering one of the basic intrusions of the locality (see No. 142).

This well-cleaved green slate is hard and brittle. The original bedding is indicated by alternate light and dark-colored bands and by frequent seams of little blackish nodules. The slaty cleavage makes an angle of about 35° with this bedding plane.

The mass of the rock is exceedingly fine-grained. It consists of quartz and probably feldspar, with flakes of micaceous minerals and a dust-like material of a darker color. From the parallel extinction of the mica-flakes they are thought to be sericite.* A parallel orientation is noticeable among these scales of mica.

The dark nodules which were mentioned in the last paragraph do not show, in the thin section, exactly what their origin may have been. They appear to be composed entirely of fibrous green chlorite through which are scattered numerous transparent inclusions most of which are probably quartz. They are ill-defined in outline, exhibit no definite crystal form, and the ends are usually rounded or ragged. Inspection of the slide shows that these fragments have been fractured and the fragments somewhat displaced, the matrix in some cases having been sheared past the ends of the grains. On the frayed edges of the grains the chlorite is minutely shredded and intermingled with the sericitic ground-mass of the slate.

No satisfactory interpretation of the nature of these bodies has been worked out. It has been suggested that they represent sand-grains of some ferro-magnesian mineral, which have since been completely altered to chlorite and quartz, and have been subsequently mashed and sheared until they have assumed their present outlines. In this case, however,

*Michel Lévy and Lacroix: Les Minéraux des Roches, p. 253.

there is serious difficulty in the fact that other constituents of sands, such as quartz and feldspar, are not represented.

Rosenbusch* and others have described rocks of a somewhat similar nature, under the name of "Knotenschiefer," from the outer zones of contact-metamorphism near massive igneous intrusions. The first writer considers them in some cases to be pseudomorphs after such contact-minerals as chiastolite and cordierite. In the described rocks, however, there is apparently no such definite arrangement of the particles parallel to planes of sedimentation as is characteristic of our specimen. Possibly the composition of certain laminæ in the rock was more favorable to the formation of these knots, and thus they developed in layers instead of promiscuously, as in the German examples.

Olive-gray clay slate, No. 128.—This is one phase of a prominent formation of greenish slates, which appears to underlie the black slates and limestones of the anthracite coal-measures on the upper Han river and is regarded as equivalent to the Sin-t'an formation. Specimen from the right bank of the Han river, 4 miles, 6.5 kilometers, below the village of Han-wang-ch'öng, Shen-si.

A soft, clay slate of olive-gray color, with a suggestion of silky luster on the flat faces. Slaty cleavage is well developed and the original bedding is not distinguishable in the hand-specimen. In weathering the rock assumes a light ocherous brown color through the production of limonite. Under the microscope it appears to consist largely of a felty mass of exceedingly minute crystals. Quartz and sericite, with a few less common constituents, are mingled with a clay-like material of olive-green color. Magnetite and quartz occur as porphyritic grains, which were probably original constituents of the clay. As in many other slates, "thonschiefer-nadeln" (supposed to be rutile needles) are scattered through the rock.

Slide No. 128 B, which is cut across the cleavage, shows the slaty character of the rock admirably (Plate LVII, Fig. D). At frequent intervals along the cleavage planes, there are lenticular bodies of quartz, which have been produced from more rounded grains by diagonal slicing and, less commonly, by granulation. Some of the smaller grains of quartz are not fractured, but show, by undulatory extinction, that they have been subjected to mechanical strain. With the exception of these grains the constituents of the rock are all arranged in thin laminæ, which are so uniform and exactly parallel that the section has the appearance of a coarse woof of cloth before the warp is added. These lines are partly composed of minute parallel sericitic flakes and a light-green micaceous mineral which is probably chlorite in exceedingly fine particles. These micas have their

*Physiographie der Mineralien, 3d ed., vol. II, p. 90.

axes all parallel except where their arrangement is interfered with by the grains of quartz to which they are obliged to conform.

Magnetite phyllite, No. 124.—The gray phyllite is one phase of the dark slates and limestones of the upper Han. Near Shï-ts'üan-hién it is interbedded between a dark gneissic magnetite-quartzite (No. 114) and black slaty limestones which include coaly strata. Specimen from a lateral ravine on the southwest side of the Han river, 3 miles, 3 kilometers, below Shï-ts'üan-hién.

A lustrous gray phyllite through which are scattered medium-sized crystals of magnetite. It is a soft rock, but has good cleavage.

The greater part of the rock is composed of finely crystalline quartz, together with abundant minute flakes of muscovite and chlorite, all of which lie with axes parallel to the cleavage of the rock. Certain thin bands have less mica than others, and so the slide presents a striped aspect not noticeable in the hand-specimen. Magnetite occurs in the form of large angular crystals and as swarms of small grains. These clusters of minute magnetites are closely associated with certain cloudy ocherous and greenish areas which appear almost isotropic between crossed nicols. This material is slightly fibrous, has a very low birefringence, and is probably chlorite discolored with earthy iron oxides. Various portions of the rock contain little prisms of tourmaline and grains of epidote.

All of the constituents of the gray phyllite appear to be of secondary origin. The composition of the rock suggests that it was originally a ferruginous shale which has been deformed in the zone of anamorphism. Under mass-mechanical conditions,* the parallel seams of quartz and micas were produced. After this process had been concluded mass-static conditions † seem to have prevailed; heavy silicates and oxides could then grow without regard to the previous structure of the rock and thus become porphyritic crystals. This probably is the origin of the few large scales of biotite and smaller muscovites, the little tourmaline prisms, and the large magnetite crystals, which lie at all angles to the schistosity and cut across the mica seams without disturbing their position in the least. In some cases the biotites are surrounded by areas poor in chlorite, limonite, and muscovite flakes, but rich in quartz; evidently the material for each large mica plate has been derived largely from the smaller minerals which formerly occupied the spot.

Pelite (?) Schists.

In addition to the foregoing rocks, *i. e.*, the slates and fine-grained phyllite, there are certain varieties of schists which are known to be of sedimentary origin because they are interbedded with limestones and

*Van Hise: A Treatise on Metamorphism, U. S. Geol. Surv. Monograph XLVII, p. 696.
†*Ibid.*, p. 701.

slates and form a continuous sequence with them. They are, however, so thoroughly metamorphosed that it is difficult to judge whether they have been produced from pelites or from psammites such as graywackes. The complex mineral composition of these schists indicates at least that they have been derived from sediments which contained a large variety of constituents. Since these rocks contain nothing suggestive of sand-grains or other coarse particles of an original nature, they will be considered provisionally as metamorphosed shaly strata.

Brown quartz-mica schist, No. 123.—This is one phase of the spotted gray schists which were so characteristic of the region north of Shï-ts'üan-hién. The present specimen exhibits the least advance in metamorphism of any of the three represented in our collection.* The rock is exposed in the canyon of the Han river, about 1 mile, 1.5 kilometers, above Shï-ts'üan-hién. There it is overthrust by the schists, gneisses, and graphitic limestones which are regarded as the Wu-shan formation.

A brownish-gray rock of medium grain, in which the schistosity is only moderately well developed. On account of this imperfection of the schistosity, and the banded appearance of the edges it might as properly be classed with the gneisses. The micas do not form continuous sheets as in typical mica schists, but are merely sprinkled thickly in small flakes over the cleavage surfaces. It is noticeable in the hand-specimen that many of the mica crystals lie transverse to the cleavage: this probably explains in some measure the breakage of the rock in directions other than along the usual planes of schistosity.

The lighter bands of the rock are composed very largely of quartz mingled with small parallel flakes of muscovite. Most of the quartz has recrystallized and forms a closely interlocking mosaic; there are a few lenticular bodies which show strain-shadows and appear to be crushed original grains.

The darker layers of the rock contain biotite and muscovite and certain rather rare accessories in addition to the abundant quartz. The biotite occurs in large rich-brown flakes which are frequently not parallel to the cleavage. It is noteworthy, however, that the smaller flakes are in all cases parallel to the schistosity. The large biotites are very ragged in their outlines and include numerous small crystals of quartz, rutile, magnetite, and zircon. The last mineral is always surrounded by the familiar dusky halos. Evidently these large micas have grown at the expense of the smaller flakes which accentuate the schistose cleavage, and are subsequent in age to the dynamic metamorphism of the rock, which produced the structure.†

*See Nos. 115 and 118.

†For an illustration of this feature see Leith: Rock Cleavage, U. S. Geol. Surv. Bull. 239, Plate XIII, B.

The section is traversed by several micro-shear-zones filled with a black coloring matter which may well be graphite.

Silvery mica schist, No. 118.—This is one of the harder phases of the abundant mica schists in the vicinity of Liang-ho. The schists are associated with thin layers of gray schistose marble.* The specimen is so nearly identical with the similar rocks in the canyon of the Han river near Shï-ts'üan-hién that there can be but little doubt as to the equivalence of the two formations.

Specimen obtained about 1 mile south of Liang-ho on the trail leading southward to Shï-ts'üan-hién.

This rock is similar in many ways to No. 123, and is evidently a part of the same terrane. The schistosity is, however, more perfect; and in addition to the flakes of biotite there is a great abundance of finely divided muscovite, which gives the rock its silvery sheen. Upon close examination it is possible to distinguish a few small pink garnets.

Thin sections resemble those of No. 123 very closely, except that the quartz is somewhat coarser grained and the plates of biotite average larger. In describing this variety it will not be necessary to repeat those details in which it agrees with the rock last described, but it will be sufficient to mention its individual peculiarities.

In the section the garnets (almandine?) are seen to be very irregular and ragged in outline. As usual they appear to have developed under mass-static conditions subsequent to the development of the schistosity, and as they grew in the rock they included many bits of quartz, magnetite, etc. A katamorphic alteration of the garnet to chlorite has begun along the numerous cracks in the mineral. Staurolite occurs in crystals quite as irregular as those of the garnet, but it is a somewhat rarer mineral. The variety here represented is yellow and exhibits no reddish pleochroism.

In addition to the more abundant minerals a few small crystals of ilmenite and pale-brown tourmaline were observed.

Like No. 123, this mica schist is a completely recrystallized sedimentary rock. Since the recrystallization and adjustment, which took place under mass-mechanical conditions in the zone of anamorphism, certain porphyritic minerals, such as garnet, staurolite, biotite, and tourmaline, have grown in the midst of the schistose mass. At a still later period there has been a certain amount of mechanical deformation which has left its impression in some of the biotite crystals, which are bent and faulted. This, however, seems to have been an episode of minor importance in the history of the rock.

*See Nos. 116 and 117.

Spotted mica schist, No. 115.—This spotted schist forms a stratum of considerable thickness interbedded between gneissic quartzite (No. 114) and black slates and limestones (No. 113), in the valley of the Han river near Shï-ts'üan-hién. There can be little doubt that the horizon is approximately the same as that from which Nos. 118 and 123 were collected. These spotted silky schists are especially characteristic of the schists which, it is thought, represent the Triassic. In general appearance the rocks do not differ widely from those which have been called the "knotenschiefer" by Rosenbusch;* but they are sedimentary rocks which have been altered under conditions of great pressure deep in the earth, while the true "knotenschiefer" are found in the contact-zones surrounding large igneous intrusions. Specimen collected in the lateral ravine on the west bank of the Han river, 1 mile, 1.6 kilometers, below Shï-ts'üan-hién.

This rock is silvery-gray in color and is distinguished by the presence of numerous small knots of black micas which impart to the rock a characteristic spotted appearance. Although the cleavage is distinct it is by no means as facile as is the parting in most mica schists. On this account it is possible to secure hand-specimens which, on account of their banded appearance, might be classed as gneisses rather than as schists. In general the rock is very similar to No. 123 and also No. 118, but it appears to represent a more advanced stage of metamorphism than either of them. In addition to the brown knots of biotite, the surface is frequently sprinkled with black, needle-shaped bodies; but these prove, on examination of the thin slice, to be merely sections of biotite crystals which are not parallel to the schistosity.

The minerals and structures in this variety are very much the same as in Nos. 118 and 123, except that staurolite was not detected. A transverse section shows that the minerals have a strongly marked parallel arrangement. Not only are the micas oriented alike, but even the quartz grains, in many instances, are somewhat rectangular and elongated in the direction of schistosity.†

Micas in this slide are olive-green in color rather than reddish-brown, as in the other two varieties above mentioned. The larger flakes, which have grown without regard to the schistosity and subsequent to the production of that structure (Plate LVII, Fig. F), are ragged in outline and include numerous crystals of quartz, magnetite, apatite, and zircon. In most cases the mica flakes are comparatively fresh, but in some an altera-

* Physiographie der Mineralien, II, 88–92.

† For an illustration of this texture see Diller: Educational Series of Rock Specimens, U. S. Geol. Surv. Bull. 150, Plate XLII; and Van Hise: A Treatise on Metamorphism, U. S. Geol. Surv. Monograph XLVII, Plate XI, C; and G. S. A. Bull. I, Plate V, Fig. 2.

tion to chlorite, magnetite, etc., is observable. As in No. 118, we find in this slide a few irregular garnets, which in the hand-specimen have a pale reddish color.

CARBONATE ROCKS.

Distorted black limestone, No. 121.—A typical specimen of the partially schistose coal-bearing limestone exposed in the canyon of the Han river, above Shï-ts'üan-hién. Specimen obtained 5 miles, 8 kilometers, above the city.

This is a dense black rock having slaty structure and conchoidal habit of fracture. The color is varied by indistinct bands and blotches of a lighter gray.

The rock is composed of minute yet visible granules of calcite. The dark color is due to the presence of a large amount of graphite, occurring in the form of black specks or of wavy streaks. Here and there one sees calcite crystals of much larger size, and usually of a lenticular shape, lying with their longer axes parallel to the indistinct banding of the rock. The streaks of graphite are also much contorted. Subsequent in age to all these features, there are numerous veins of calcite which cross the rock in various directions.

This limestone has been notably, although not severely, metamorphosed. The contorted bands of graphite and the lenticular calcite bodies, embedded in a matrix which possesses a slightly schistose structure, indicate that the mass has been considerably deformed. Very little progress has been made, however, in the crystallization of the rock, and some of the larger bits of calcite resemble pieces of distorted fossil shells.

Buff siliceous dolomite, No. 135.—The buff dolomite is associated with black slates (No. 133) and gray limestones in the valley of the Nan-kiang, about 1.5 miles, 3.5 kilometers, north of Pai-kiu-hia. In color, although not in composition, it resembles the buff marble near Liang-ho, and also certain limestones of the central part of the Ts'in-ling range.

This is a dense aphanitic rock of light-buff color, traversed by veins and irregular masses of white quartz.

The buff-colored portion is composed of minutely crystalline dolomite among which rhombic forms are frequently visible. The white patches consist of vein quartz which, if we may judge from its undulatory extinction, has been subjected to intense strain. The greater part of this quartz has been sliced and granulated and the resultant debris has been arranged in parallel streaks of elongate ragged crystals. Dolomite is scattered through this mass in the form of irregular bodies, rhombic crystals, or more frequently as skeleton crystals which are intergrown with the quartz.

This slide shows admirably the very different behavior of quartz and dolomite under conditions of strong compression. The former is broken, ground up, and stretched out in bands; the other adjusts itself to the new conditions by merely recrystallizing in the form of a homogeneous aggregate.

Black crystalline limestone, No. 113½.—This coaly limestone is associated with thin layers of impure black slate and dark limestone, along the canyon of the Han river opposite Shï-ts'üan-hién.

Specimen from the right bank of the river, 1 mile, 1.6 kilometers, below the city.

This is a coal-black finely crystalline limestone in which the lines of stratification are bent and contorted. The body of the rock is composed of interlaced crystals of calcite, arranged after the fashion of marble. A black graphitic substance occurs as specks included in the crystals and also in much greater amount in the form of streaks and seams; as the crystals formed they evidently excluded most of the graphite and pushed it aside. In addition there are grains of magnetite and quartz and small flakes of colorless mica; all of these are scattered indiscriminately through the rock, but the mica flakes lie with their axes parallel to the minute shear-zones which traverse the slide. Here and there the rock has been torn apart in the process of folding, and the fissures thus formed are now filled with vein quartz.

The original components of this limestone have entirely recrystallized under conditions of dynamic metamorphism and have formed crystals of calcite, secondary quartz, mica, etc.

Gray schistose limestone, No. 119.—This is from one of the limestone layers which are interbedded with mica schists, near Liang-ho. It is therefore closely related to Nos. 116 and 117. Specimen collected 3 miles, 5 kilometers, southeast of Liang-ho.

This rock is a dark-gray fine-grained limestone, banded with white laminæ of quartz. Much of the mass is distinctly foliated and the surfaces of these foliæ carry minute flakes of mica, which impart a silvery sheen. The dark bands consist of interlocking calcite crystals, the majority of which are arranged with their longer axes nearly parallel. This schistose structure is emphasized by streaks of graphite, which coincide with it in trend. Pyrite and bits of graphite are scattered indiscriminately through the rock, while little scales of muscovite lie with their axes parallel to the general banding. The darker laminæ are relatively free from quartz, but the white layers are composed almost entirely of that mineral in the form of a clear mosaic. The quartz shows little, if any, evidence of deformation, and it appears to have been deposited after the rock had passed through its severest distortion.

Buff micaceous marble, No. 117.—This buff marble occurs in layers 2 to 4 feet in thickness, embedded in biotite schists (No. 115) from Liang-ho to Ta-ho-pa. The series is evidently equivalent to a portion of the Paleozoic rocks exposed in the canyon of the Han river, and referred to the K'ui-chóu schists, but in this northerly district metamorphism has been considerably more severe. Specimen from the summit of the first hill northwest of Liang-ho, Shen-si.

An ocherous buff marble, the texture of which varies in different parts of the same specimen from fine-grained to rather coarse. Flakes of muscovite and ferrite are scattered freely throughout the mass, but are especially abundant along certain roughly parallel laminæ. The rock is not, however, distinctly schistose.

It is composed very largely of dull, cloudy crystals of calcite in which cleavage cracks are unusually prominent and closely spaced. In addition there are small crystals of quartz and muscovite which are scattered about without distinct orientation. Clouds of earthy limonite and other dark stains are prominent. There are also a few decayed scales of biotite, small crystals of tourmaline and apatite, and brownish grains of rutile.

It is evident that this rock has entirely recrystallized. The muscovite is often inclosed in calcite and probably developed earlier than the latter. All of the quartz shows undulatory extinction, and thereby indicates that the rock has been subjected to severe strain since it attained its present condition.

Gray micaceous marble, No. 116.—The same as No. 117. It is a gray sugary marble, indistinctly banded with a darker shade. Both light and dark micas are abundant along certain planes in the rock, but they are rare in other parts of the mass; the rock is, therefore, partially schistose.

This variety so closely resembles the last in everything but color that it will be sufficient to mention simply a few points of difference. Unlike No. 117, this marble contains rather more biotite than muscovite, and the color is due to the presence of graphite instead of ferruginous matter. The biotite flakes are reddish-brown, the pleochroism varying to pale greenish. The flakes of this mineral are small and arranged in parallel sheets after the manner of schistose rocks in general. Some of them are bent and more or less crushed, evidently by movements which have taken place subsequently to the crystallization of the rock. The micas include minute crystals of zircon, tourmaline, and rutile. The alteration of the biotite produces a pale chlorite, and small grains of iron ore separate out during the process.

Apparently this marble could have been produced from such a rock as No. 119 by more severe dynamic metamorphism. The calcareous portion of the rock has formed interlocking calcite crystals of considerable

size, while the clay-like impurities have been wholly reorganized into such minerals as mica, tourmaline, etc.

White dolomitic marble, No. 120.—A portion of the gray limestone of the coal-bearing series. It probably owes its unusual crystallinity to the fact that it has been strongly metamorphosed by the intrusion of igneous rocks (Nos. 126 and 127) which lie adjacent to it. Specimen from the right bank of the Han river, 6.5 miles, 10.5 kilometers, west of Shï-ts'üan-hién.

A medium-grained, uniformly crystalline marble of grayish-white color. No accessory minerals are visible, and there is no evidence of schistosity. By the rapid weathering of the small amount of calcite which is present, the dolomite crystals are left upon the surface and form a friable exterior coating.

The rock is composed of interlocking crystals of dolomite with a small amount of calcite. As these minerals occur here in almost the same condition as to size, shape, and position of crystals, it is almost impossible to distinguish the two except by treatment with acids. All of the crystals are relatively irregular, the rhombic outlines being rarely perceptible. The opaque white color of the rock is apparently due to the fact that the larger dolomite crystals contain many small inclusions of carbonate; these serve to break up and reflect incident light.

This is a very pure dolomitic marble, containing no bodies of quartz nor any other foreign minerals. Since the complete recrystallization of the mass the rock has been fractured and in places brecciated. The cracks thus formed are now sealed with veins of fine-grained calcite, the transparency of which contrasts with the somewhat cloudy body-material of the rock.

Rocks of Igneous Origin.

The igneous rocks of the Han river district readily divide themselves into two groups. The first group contains the granites, and of these we have no specimens.* The other division comprises holocrystalline rocks of basic composition, the majority of which may be classed as gabbroids. In all cases the rocks occur as rather deep-seated intrusions. Neither surface volcanics nor porphyry dikes were observed at any point along our route in western China.

Black amphibolite, No. 125.—This rock occurs as a dike in the metamorphosed Carboniferous strata, in the valley of the Han river near Shï-ts'üan-hién. Specimen obtained in the tributary ravine on the right bank of the Han river, about 1 mile, 1.5 kilometers, below Shï-ts'üan-hién.

*For a description of Post-Carboniferous granite of Tsin-ling mountains, see page 440.

A medium-grained, greenish-black dike-rock of even texture. Probably 85 to 90 per cent of this rock is composed of a blue-green hornblende. It occurs usually in ragged interlacing bundles or long rods. In some places it appears to be fairly compact, being somewhat frayed only at the edges. Throughout the rock, even in the areas where quartz and other minerals predominate, detached rods of hornblende are abundant. These bodies are not separate crystals, but are apparently shreds of larger crystals such as would be formed if the hornblende were torn apart along the two prominent cleavage planes. Although the mineral is relatively fresh, there are numerous areas which are blackened by the separation of iron ores in minute particles, with or without quartz and calcite. Such alterations as these are evidently the result of recent weathering. It is highly probable that this secondary hornblende has been derived from pyroxene, but there remains nothing either of form or substance which can be definitely relied upon as a clue in seeking the origin.

Spaces not occupied by the hornblende are now filled with clear quartz inclosing abundant grains of epidote and occasionally other minerals. These are doubtless the end-products of the complete alteration of original pyroxene and feldspar. The bulk of the material has been constructed into hornblende, leaving an excess of quartz and epidote filling the interstices. In addition to epidote and quartz, these light-colored areas contain a few irregular crystals of zoisite and a colorless garnet which is probably grossularite.

The iron ores occur in rather large, irregular bodies. Pyrite is plentiful, but ilmenite is the more common variety and is almost invariably bordered by titanite. Titanite also occurs in granules, and these granules are sometimes aggregated into dense clusters of considerable size. The granular occurrence of the titanite and its close association with ilmenite suggest that it is a secondary product due to alteration of the latter. The alteration of ilmenite to leucoxene, known to be a finely divided form of titanite, can be observed in this slide. The granular titanite could readily be produced by the crystallization of the leucoxene. Thus bits of ilmenite which were only partially changed would be surrounded by borders of titanite; while granular sphene would occupy the places of other fragments which had been entirely altered. In this case the iron has not produced magnetite, but has been disposed of in some other way.*

The pyrite occurs in irregular bodies which are sometimes more or less completely inclosed in a carbonate which can not be distinguished from calcite.

*For the usual reaction, see Van Hise: A Treatise on Metamorphism, U. S. Geol. Surv. Monograph XLVII, p. 227.

All of the minerals in this rock, with the possible exception of the iron ores, appear to be of secondary origin. There is no trace of mechanical deformation in the specimen, but the entire substance of the rock seems to have recrystallized into new minerals. Originally the rock was probably a basic gabbro.

Poikilitic saussurite gabbro, No. 137.—This gabbro is a fair sample of the basic intrusives* which are common along the Nan-kiang in southern Shen-si. The rocks usually occur in the form of large dikes, scores of feet in thickness. All of these intrusions break through folded Paleozoic rocks and are almost certainly of Post-Triassic age. Specimen collected 0.5 mile, 0.8 kilometer, northeast of Pai-kiu-hia.

The rock is holocrystalline, but the different constituents are not readily distinguished in the hand-specimen. The mass has a uniform dark-gray color somewhat lighter in indefinite patches. Owing to the intergrowth of large pyroxenes and small feldspars, fresh surfaces exhibit the feature which has been variously called "luster mottling" or poikilitic texture. Grains of ilmenite and pyrite are easily seen with the unaided eye.

The rock in its present condition consists of augite and alkali feldspars, together with such accessory minerals as brown hornblende, apatite, ilmenite, pyrite, titanite, and zircon.

The augite has a very pale violet-red color, but is not pleochroic. The outlines of the large augite crystals are controlled by the numerous feldspar laths and are therefore quite irregular. Along the various cracks and edges the pyroxene has been altered, producing a fibrous green chlorite, calcite, and minute needles of a colorless amphibole. These needles extend out from the cracks into the chlorite, and they always preserve a parallel orientation with reference to the principal cleavage of the original pyroxene. From the absence of color the needles are believed to be tremolite. It is inferred that the augite is not rich in iron, for magnetite and other ferruginous minerals have not been produced in the process of alteration.

The feldspars which are now present are albite with a little orthoclase. It is strongly suspected, however, that these are not primary minerals. This inference is supported by the fact that the alkali feldspar occurs in clear, fresh-looking crystals associated with an abundance of zoisite and epidote. In order to produce these lime-bearing minerals in such large quantities, there must have been present some primary mineral which was rich in lime. Augite contains a small amount of calcium, but the alteration of the pyroxene has not proceeded far, and much of the lime is

*A brief description of this rock, under the name of diabase, has been published by Dr Karl Vogelsang (Peterm. Mitth. 1904, p. 18).

required for the production of the tremolite associated with it; the augite, therefore, seems to be inadequate as a source for the supply of lime required to form the zoisite. Furthermore, rocks which are rich in augite and the titanium minerals usually contain calcic feldspars rather than the alkaline varieties. It is suggested, therefore, that the present feldspars of this gabbro have been derived from calcic plagioclase. Becke* describes the alteration of plagioclase plus orthoclase into albite, zoisite, quartz, and muscovite. Without orthoclase we should have no muscovite and hence a condition similar to that observed in the present rock.

Brown hornblende is of rare occurrence and is altered for the most part into chlorite, zoisite, and iron ores. It seems to have been reddish-brown originally, but with the exception of a few lingering spots the mineral has become bleached during the earlier stages of alteration and appears nearly colorless. This bleaching almost destroys the pleochroism, but it does not seriously affect the birefringence; under crossed nicols, therefore, the brown and bleached areas are not easily distinguished.†

Although ilmenite and pyrite are both common, the former is much the more abundant. Titanite frequently forms borders surrounding the ilmenite and also occurs in irregular masses of relatively large size; most of the ilmenite is now altered to the gray powdery form of titanite known as leucoxene.

It is unnecessary to make further mention of any of the secondary minerals except the zoisite. This appears in the form of irregular grains or short crystals which are either distributed separately or in clusters throughout the rock. Very frequently crystals are embedded in masses of chlorite. Many of the zoisites possess a brownish or dusty aspect which is due to the presence of excessively minute inclusions.

Augite syenite, No. 142.—Inasmuch as this specimen was taken from the extreme periphery of the intrusion, it is probably not typical of the igneous rock. Although it now has the composition of a true syenite, it is not improbable that it was derived by magmatic differentiation from a more basic rock like the gabbro last described (No. 137).

Specimen collected from debris in the great landslide of 1901, 4 miles, 6.5 kilometers, south of Pai-kiu-hia.

Our specimen shows the contact of a syenite with the green shales which have been transformed by the intrusion into a soft, dense, chlorite rock. The intrusive itself is a moderately fine-grained greenish-gray rock of even texture and without porphyritic crystals. The feldspars and the darker minerals are fairly well contrasted, so that the rock has a finely

* Neues Jahrbuch für Mineralogie, etc., vol. II, 1896, p. 182.

† Similar bleaching of the hornblende has been described by Williams, from the greenstones of Michigan (U. S. Geol. Surv. Bull. 62, pp. 79 and 126).

speckled appearance. The chloritic hornfels with which it is in contact is a dense, dark, green-gray rock which shows no trace of its original structure. It is pierced by numerous radiating tubular bodies of quartz, with zoisite, which radiate outward from the contact.

The mass of the rock consists of medium-sized and fairly idiomorphic alkali feldspars, with hornblende, augite, and various accessory and secondary minerals, such as quartz, ilmenite, sphene (and leucoxene), apatite, zircon, actinolite, epidote, zoisite, chlorite, and tourmaline.

The feldspars are largely albite, but there are also many scattered bodies of orthoclase. In general the feldspars are quite fresh, and exhibit no features which can be referred to as surely of a secondary nature. Granules of zoisite are, however, scattered abundantly throughout the rock, and it may be that they are alteration products derived from more calcic feldspars which have been completely changed into alkali feldspars and zoisite, as suggested in the case of No. 137. The facts observed do not permit us to decide upon this question.

Of the common ferro-magnesian minerals, both augite and hornblende are present. Sometimes the amphibole incloses the pyroxene, but usually the two minerals occur in separate bodies. The pyroxene is colorless except for the cloudy brown products of alteration by which most of it is obscured. From the edges of the crystals needles of a pale amphibole (actinolite?) have grown outward as a fringe, while secondary chlorite has invaded the crystals irregularly. It is, therefore, much decayed.

The original hornblende was brownish, as is indicated by certain brown patches which still remain. This has been extensively changed to a green color, and even the green has in a large measure been bleached out, so that many of the crystals now appear as pale-greenish amphibole possessing only the faintest pleochroism.* Alterations of the hornblende, like those of the pyroxene, result in the formation of chlorite and a fibrous amphibole of pale emerald-green color. The abundant grains and small crystals of zoisite, with more or less of epidote, which are so closely associated with these greenish minerals, may have been derived in part from the alteration of primary amphiboles and pyroxenes.

Some of the larger crystals of zoisite inclose yellowish epidote. Apatite forms rather large prisms, and zircon is quite rare. Although the titanium minerals are not abundant, ilmenite with secondary leucoxene and sphene are present in considerable quantity.

Contact phenomena.—The syenite is in sharp contact with a hornfels which represents the green slates of the Sin-t'an formation.† This horn-

*References to these changes in hornblendes have already been made in connection with No. 137.

†For a slightly metamorphosed phase of these slates, see No. 141.

fels is composed entirely of chlorite, which appears homogeneous in ordinary light, but polarizes in very irregular fashion. Between crossed nicols the beautiful ultra-blue color is very prominent and distinctive. The exact line of contact between the igneous rock and the hornfels is usually discolored by yellowish-brown matter.

Within a few centimeters of the syenite long tubular stringers of quartz and prisms of zoisite extend radially out into the country rock; the former are very conspicuous in the hand-specimen. Smaller crystals of zoisite and hornblende are clustered along the contact or lie embedded in the chloritic mass. Most of these show plainly by the bent crystals and strong undulatory extinction that they have been subjected to intense strain. This is perhaps a result of the pressure exerted on the surrounding rock by the advance of the intruded magma. The lacerated edges of the hornfels, the shear-zones in the quartz and the repeated cross-fractures parallel to the contact are possibly to be explained by the "drag" of the still viscous body of the lava, the extreme edges of which had already solidified. One thing at least is clear, viz, that the quartz tubules are genetically connected with the intrusion of the syenite, for they are not present anywhere except along its immediate boundaries.

Schistose greenstone, No. 126.*—This greenstone forms a large mass of unknown extent, which has apparently been intruded into the Paleozoic sedimentary formations about 7 miles, 11 kilometers, west of Shĭ-ts'üan-hién, on the Han river. The mass is greatly decayed and is so thoroughly broken by intricate systems of joints that it is difficult to obtain a satisfactory specimen of the rock.

Specimen from the south bank of the Han river, 7 miles, 11 kilometers, above Shĭ-ts'üan-hién.

The rock is dark greenish-gray, massive and aphanitic in texture. The hand-specimen exhibits no definite structural peculiarities, for in spite of its schistose microstructure it shows no tendency to cleave along parallel planes, but breaks up in the irregular manner which is so characteristic of greenstones generally.

The rock is very fine-grained and consists largely of pale-green hornblende with quartz and probably feldspar. Pyrite and magnetite are common although not abundant accessories, while zoisite and epidote are also present in considerable quantities.

A minute schistose structure is prominent in the thin sections. The smaller and more fibrous crystals possess a parallel arrangement and inclose larger lenticular bodies or "augen." The schistose lines are wavy

*According to Van Hise, this would be a hornblende dolerite, but the term here used is preferred on account of the fact that it is non-committal in regard to the origin of the rock.

and interwoven rather than strictly parallel. The fact that the rock is cohesive rather than slaty is probably due to this interlacing of the fibers.

There can be little doubt that the green hornblende is a secondary derivative from pyroxene, by the process commonly referred to as "uralitization." Although no traces of that mineral remain, sections of some of the less distorted hornblendes are nearly rectangular instead of rhombic, and thus suggest the form of augite. This hornblende occurs both as irregular compact bodies in the "augen," and in the form of fine needles arranged with their axes parallel to the schistosity. The latter often indicate by their relation to the larger bodies that they have been derived from the latter by "slicing"* or by recrystallization of the hornblendic material, or by both processes combined.

The original feldspars of the rock were presumably lime-bearing plagioclases. They are now completely saussuritized, having been replaced by finely granular zoisite, quartz, and alkali feldspar. These materials are scattered through the ground-mass or occur in the lenticular areas in which phenocrysts formerly existed. In these bodies it is not uncommon to observe yellowish centers, such as Williams described with reference to some of the Michigan greenstones.†

The minerals of this greenstone are almost all of secondary origin. The original rock was probably a basaltic porphyry, *i.e.*, one composed in large measure of pyroxene and a basic feldspar. It appears to have undergone two distinct episodes of alteration: first, a mass-static change in which pyroxene was transformed to hornblende, and feldspar to saussurite; second, a mass-mechanical transformation which developed the schistose structure. In the latter process the materials of the ground-mass became arranged in rough parallelism, the amphiboles in long fibers and the other minerals in attenuated streaks of granules. At the same time the pseudomorphs, after the phenocrysts were deformed into lenticular bodies, were fractured, faulted, and bent, and were reduced by marginal slicing and recrystallization. The mass-mechanical change was not permitted to proceed very far toward the ultimate goal of such a process, which would be the formation of a coarse-grained amphibole schist. While undergoing the first of these alterations the rock was probably in the zone of katamorphism;‡ but during the second period it must have been subjected to greater pressure than obtains in that zone. The intense folding, which the rocks of that locality are known to have suffered, is probably ample to account for the moderate deformation of this greenstone. Since the close

*C. K. Leith: Rock Cleavage, Bull. 239, U. S. Geol. Surv. p. 30.

†U. S. Geol. Surv. Bull. 62, p. 145.

‡Van Hise: A Treatise on Metamorphism, Monograph 47, U. S. Geol. Surv., pp. 260 and 279.

of the epoch of mass-mechanical change, the rock has been subjected to the tensile strains of which we have evidence in the numerous sharp fissures which are now sealed with vein quartz.

White aplite, No. 127.—This intrusive was found about 7.5 miles, 12 kilometers, above Shï-ts'üan-hién, in the canyon of the Han river. At that point it is in contact with metamorphosed dark limestones and it separates these sedimentary rocks from the mass of greenstone which lies to the westward. Its relation to the limestones is evidently that of a subsequent intrusion, but the contact between the felsite and the greenstone was not observed. It is possible that this acid rock is genetically connected with the greenstone, and that it was developed from the basic magma by the process of differentiation which occurs in fluid lavas. It is more probable that the felsite is a dike of later age than the greenstone and that it was intruded along the contact between the basic rock and the sedimentary strata.

This is a stony aphanitic rock which, on fresh surfaces, is greenish-white, but which weathers to a buff color on account of a small amount of ferruginous material which it contains. The rock exhibits no definite structure, but in the particular situation observed it is traversed by numerous closely spaced joints, so that it was not easy to obtain a specimen of the desired size.

The thin section shows that the rock is composed of a finely granular ground-mass composed entirely of colorless quartz and feldspar. In these are embedded a few moderate crystals of orthoclase, but quartz is not represented among the phenocrysts. A closer inspection of the slide shows that there are parallel layers in which the constituents are alternately either coarser or finer than in adjacent layers, suggesting incipient schistosity.

The phenocrysts of orthoclase are filled with secondary inclusions of micaceous minerals. During the deformation which the rock has suffered, some of the phenocrysts have been fractured and the fragments more or less displaced. The fissures thus produced are now sealed by veins of fresh feldspar or sometimes quartz and feldspar together. About the edges of the phenocrysts, and particularly before and behind the crystal with reference to the lines of banding, granulation of the feldspar has taken place, and the detritus thus produced has in large measure recrystallized in the form of fresh interlocking grains free from inclusions. The corners of the "eye-spots" are frequently filled with new quartz rather than feldspar.

The ground-mass is made up of minute irregular but rounded grains of quartz and clear limpid orthoclase. The feldspar is present in somewhat greater abundance than the quartz. With the exception of certain masses

of a grayish amorphous material, which may be leucoxene, only one other mineral appears in the slide. This is a pale-greenish muscovite, a few small flakes of which are scattered through the ground-mass. In the arrangement of these flakes there is a marked parallelism to the banding of the ground-mass, and it is, therefore, evident that the mineral is one of those developed during metamorphism of the rock. Certain square cavities in the slide strongly suggest that magnetite is present in the rock, but that all the grains have been rubbed out in the process of grinding the section.

This rock has the mineral composition of an aplite. Originally the texture was densely felsitic, but the primary texture has been somewhat modified by the mechanical deformation of the mass and the recrystallization of a small part of its constituents. Although the parallel orientation of mineral particles is perceptible in the thin section, no tendency toward schistose cleavage is to be noted in the rock.

YANG-TZÏ GORGE DISTRICT.

In a general way this is the region long known as the "Yang-tzï Gorges." We shall include in this district the valley of the Yang-tzï river, from I-chang-fu (in the province of Hu-peï) westward to Wu-shan-hién, together with all of the drainage slope north of the river. It thus comprises not only the valley of the great river, but also several northern tributaries such as the Ta-ning-ho, a stream which we followed from one of its sources to its mouth.

The rocks of this district are for the most part of Paleozoic age with local exposures of Mesozoic and Pre-Cambrian terranes. They are strongly but not intensely folded, and with the exception of the oldest formations, they are not notably metamorphosed. In the numerous deep canyons, which have been cut by the Yang-tzï and its tributaries, these formations are exposed with a clearness which is surpassed in very few parts of the world.

PRE-CAMBRIAN.

The granite which underlies the Paleozoic sequence of stratified rock, at the head of the I-chang gorge, is probably only a part of a complex Pre-Cambrian mass which is composed of gneisses, schists, and igneous intrusives of various kinds. Rocks of this character were observed by Pumpelly, at the mouth of the Lukan gorge,* and in the glacial beds at the base of the Paleozoic limestones at Nan-t'ou we found numerous boulders of clay slates, siliceous limestones, dark schists, granite, and porphyry. At present, however, the Huang-ling granite appears to be the only member of this complex of which specimens have been collected and studied.

*Smithsonian Contributions to Knowledge, vol. xv, Geological Researches in China, Mongolia, and Japan, p. 4.

ROCKS OF IGNEOUS ORIGIN.

GRANITIC ROCKS.

*Gneissoid quartz-diorite,** *No.* 148.—This quartz diorite is known from a single locality only, namely, the village of Nan-t'ou at the head of the I-chang gorge of the Yang-tzï river. Here it forms the basement upon which the lowest Paleozoic sediments were deposited. Although its relation to the other Pre-Cambrian rocks is wholly unknown, it must be supposed that it was intruded in Pre-Cambrian times into other rocks of still greater age.

This is a medium-grained black-and-white granite in which a distinctly banded structure is visible, especially when a large body of the rock is inspected; in small hand-specimens the feature is by no means prominent. The lighter minerals appear to consist of quartz and colorless feldspars, while biotite and hornblende, in nearly equal proportions, constitute the darker portions of the rock.

The feldspar probably makes up more than half of the mass. The mineral is a sodic plagioclase, whose composition appears to be approximately Ab_2An_1, and is therefore intermediate between oligoclase and andesine. The crystals are more or less obscured by irregular patches of alteration products which apparently consist of kaolin and zoisite, with a few flakes of muscovite and bits of epidote. These decayed areas appear under the microscope as a pale grayish aggregate with irregular polarization colors.

As is usual in granitic rocks, the quartz was one of the last minerals to crystallize and now occurs in very irregular masses. The mineral requires no special description in this case, except the statement that it not infrequently includes trichites and other crystals of minute size.

The hornblende is the dark-green variety which is usually found in the granitic rocks. The crystals are irregular in shape and in orientation. For the most part, the hornblende is relatively fresh, yet alterations of several sorts have made some progress. In most cases chlorite and epidote are the products of the change—an alteration which has evidently taken place while the rock was in the zone of katamorphism. In other cases the hornblende has altered into longitudinal streaks of a brown serpentine-like product which alternate with seams filled with pleochroic greenish fibers which are probably uralite.

The biotite is somewhat less abundant than the amphibole. Its color is rich olive-brown. The origin of this mica is not obvious, but the occurrence of the flakes in seams and streaks, which are roughly parallel, and

*Pumpelly has described this and two other related varieties from the same region. (Smithsonian Contributions to Knowledge, vol. xv, Geological Researches in China, Mongolia, and Japan, p. 4.)

thereby impart to the rock its banded structure, compel the belief that it is the result of dynamic metamorphism. This is further indicated by the intimate relations of the biotite to hornblende. In the case of one large hornblende which is not parallel to the banding, a large cavity in its side is occupied by a biotite scale which is oriented with reference to this structure of the gneiss. The formation of biotite from hornblende in presence of potassic feldspars is known* to occur frequently under anamorphic conditions and is an important factor in the making of many schistose rocks. The biotite itself has altered in this case to chlorite, the new mineral developing in narrow streaks parallel to the cleavage of the mica. At the same time fibers of rutile separate out, thus showing that the biotite was titaniferous (Plate LVI, Fig. B). Not infrequently epidote has also been produced as a result of these changes.

Of the rarer minerals the iron ores are the most prominent. Magnetite and ilmenite are both common, while pyrite is rather rare. They occur in comparatively small grains or irregular bodies. Titanite, although not abundant, is widely distributed and is sometimes found bordering masses of ilmenite. Apatite and zircon are present as in most of the granitic rocks.

Whatever may be the history of this rock it now shows comparatively little evidence of having been severely metamorphosed. The roughly parallel streaks of mica are thought to have been developed under such conditions, and it is probable that the hornblende was the original ferromagnesian mineral which provided much of the material to form this biotite. Aside from this, however, we can distinguish very few changes which occurred while the rock was subjected to the conditions which obtain in the zone of flowage; most of the other alterations observable are those which characterize the zone of katamorphism. The quartz grains, and to a less extent the feldspars, exhibit strong undulatory extinction, indicating that they have been severely strained, without being actually fractured. In only a very few places in the slide is it possible to observe fracturing or granulation of the minerals, and it is very doubtful if, barring the formation of the biotite, any considerable portion of the mass has recrystallized.

PALEOZOIC.

The Paleozoic rocks of the Yang-tzï region are sedimentary in origin. Not a single dike of igneous rock, either of this age or of any later period, has yet been found in the district.

The stratified rocks consist of limestones and shales with occasional quartzitic sandstones; locally there are certain boulder clays which are of

*Van Hise: A Treatise on Metamorphism, U. S. Geol. Surv. Monograph XLVII, p. 288.

glacial origin. None of these rocks have been metamorphosed to any noteworthy degree—taking the word "metamorphism" in its prevalent and restricted sense. They have undergone only such changes as take place at moderate depths, *i. e.*, cementation, advance in crystallization and weathering.

Rocks of Sedimentary Origin.

Psammites.

Reddish sandstone, No. 150.—This sandstone is the basal member of the Paleozoic system at Nan-t'ou on the Yang-tzï. The specimen was taken about 50 feet, 15 meters, above the unconformable contact with the underlying granitic rock.

A dull reddish-brown rock of medium grain. The color and texture are nearly uniform. Although somewhat friable, the rock is well cemented and relatively hard.

The subangular and closely packed grains consist very largely of quartz. In addition there are several varieties of feldspars, iron ores, flints, etc., amounting to perhaps 15 per cent of the rock. These fragments are joined together partly by a filling of clay, but even more by quartz, which has been brought in and deposited upon the sand-grains, the material thus added having the same crystallographic orientation as the original grain. These secondary borders are sometimes very broad. The clay-like filling appears as a brightly polarizing fibrous mass which is so fine-grained that the components are not distinguishable; probably it consists of kaolin, sericite, and perhaps talc discolored by iron oxides.

The sandstone has suffered but little change except the cementation just alluded to. Aside from strain-shadows in some of the grains, no effects of compression are noticeable.

Pink sandstone, No. 149.—This is merely another phase of the same sandstone as No. 150, which it resembles closely in both texture and solidity. It differs chiefly in containing much less ferruginous matter, and on this account its color is much lighter. In this specimen bits of muscovite and hornblende may be seen with the unaided eye.

Greenish quartzite, No. 144.—A very thin local layer near the top of the green shales of the Sin-t'an formation. The rocks of the vicinity are folded, but have not been subjected to great compression and are, therefore, relatively little altered.

Specimen collected in the canyon 2 miles, 3 kilometers, north of Ta-ning-hién, Ssï-ch'üan.

A dense fine-grained quartzite, which fractures conchoidally. The color is a uniform dull olive-gray, and the weathered surfaces are ocherous brown.

The thin section shows a fine-grained mosaic of quartz, with a small amount of feldspar and bits of other minerals. The grains are now decidedly angular, and either interlock with each other after the manner of a crystalline rock, or are cemented together by a greenish clay-like material which occupies all interspaces. In addition to the predominant quartz, one sees scattered grains of orthoclase, microcline, and plagioclase feldspars and also small bodies of iron ores, tourmaline, rutile, zircon, etc. The zircons are very small, but they are unusually numerous in this rock. It is difficult to resolve the greenish cement-material into its components; they appear to be chlorite, delessite, and limonite.

The rock was formerly an impure sandstone, the pores of which were filled with a greenish clay. The induration of the rock has been effected in part by the secondary enlargement of the quartz grains, but principally by the crystallizing of the earthy material filling the interspaces. The effects of compression are almost negligible. Some of the crystals show strain-shadows and the slide is crossed by a few irregular cracks along which earthy iron oxides have been concentrated. There is no evidence that the mass has been severely strained or that recrystallization has progressed beyond the merest beginnings.

Carbonate Rocks.

Black flinty dolomite, No. 151.—A prominent member in the lower portion of the Ki-sin-ling limestone, the horizon being about 200 feet, 60 meters, above the glacial shales at the locality visited. The rocks are thin-bedded, and the nodules of flint are quite evenly distributed over the surface of the slabs. Specimen collected 0.75 of a mile, 1.2 kilometers, east of Nan-t'ou, Hu-peï.

This is a dense coal-black limestone in which are embedded numerous disc-shaped or spheroidal nodules of black flint 1 to 3 cm. in diameter. These bodies are most prominent on the weathered surfaces, partly because they stand out in relief and partly because such surfaces take on a grayish color, while the flints themselves remain black. The rock is very hard and does not react with cold hydrochloric acid, except around the circumferences of the flint nodules.

The great mass of the rock consists of minute rhombic crystals of clear dolomite associated with much dark bituminous matter. The flint nodule shown in the slide gives a circular section with a circumference of great regularity. The structure of this body is roughly concentric, the outer portions being unlike the inner (Fig. 70). The peripheral part is composed of relatively large crystals of calcite, some of which are distinctly rhombic in form; this calcite appears lighter than the rest of the rock, because it contains less carbonaceous matter. Toward the center of the nodule the

calcite crystals are more perfect and in many cases are separated from each other. The interspaces between these carbonates, as well as the entire central portion of the nodule, are filled with fine-grained irregularly polarizing quartz, such as is characteristic of flint. In this quartzose filling occasional small rhombs of calcite are embedded, and the whole of it is colored brown by carbonic material.

The question of the origin of the flint nodules is of interest. Structurally, these nodules are geodes. The calcite was evidently deposited from solution as the lining of a spherical cavity and this deposition of carbonate did not proceed to completion. The remaining space in the interior of the geode was completely filled with silica and carbonaceous matter, thus converting the cavities into solid bodies. In the majority of cases this flinty filling makes up by far the greater part of the nodule, and its superior hardness causes it to remain prominent when the shell of calcite has been dissolved away.

Black oolite, No. 143.—A layer in thin-bedded argillaceous limestone of buff, brown, and black colors. This is probably the lower portion of the Ki-sin-ling formation of Cambro-Ordovician age. Specimen collected 2 miles, 3 kilometers, above Ta-miau-ss'i, east Ssï-clı'üan.

This is a dense dark-gray limestone containing countless spherical black bodies which average little more than 1 mm. in diameter. As the rock fractures these spherules are broken through at all angles.

The circular bodies appear brown in this section because of finely divided carbonaceous material embedded in a mass of calcite. The spherules are rarely in contact with each other and the edges are never indented. Each of them is more or less completely bordered by a fringe of long calcite prisms arranged radially. The granular matrix always lies outside of this fringe; and in the smallest interspaces it is absent because the fringes fill the entire cavity between the spherules.

The individual oolitic bodies are nearly spherical in almost all cases, and vary from 0.5 to 2 mm. in diameter (Plate LV, Fig. C). Generally, no distinct nuclei can be recognized, but in one case a large rounded crystal of calcite plays this rôle. Usually the central portion is merely somewhat more coarsely crystalline, but otherwise not different from the rest of the granule. The outer portion of each spheroid is marked by faint concentric rings of brownish pigment. The body-material is calcite, but the particles are so minute that most of them are not visible, even under a high-power objective. The radial streaks seen in many oolites can scarcely be detected in this specimen.

This black variety marks a stage intermediate between the red oolites (Nos. 14 and 10) and the black oolites (Nos. 17 and 18) of Shan-tung.

From the former it differs not only in lacking the ferruginous material, which brings out so prominently the structures in those specimens, but in being slightly more advanced in crystallization. On the other hand, by an increase in the size of the crystals this would readily pass over into such a rock as No. 17.

Gray dolomitic oolite, No. 152.—The exact horizon which is characterized by this limestone is not known, although it will doubtless be found within 500 feet, 150 meters, of the base of the Ki-sin-ling formation. The specimen was taken from talus blocks which had rolled down from the cliffs 0.75 of a mile, 1.2 kilometers, east of Nan-t'ou, on the Yang-tzï.

A light-gray rock in which a granular texture can be detected even with the unaided eye. It contains abundant small rounded bodies of various shapes and sizes, most of them like the ground-mass in color, but in some cases either darker or chalky white. In no other specimen, among the Chinese oolites, do these bodies exhibit such diversity of shape as we find here. They are rarely spherical, but are more often irregularly rounded or flattened, the surface being lumpy or pustulate. In no cases, however, are they either elongate or angular.

In this slide the majority of the globules are distinguished from the matrix only by the dark borders which surround them. Both within and without these borders the rock consists of a medium-grained mosaic of clear calcite, with which are associated irregular grains of dolomite which may be distinguished by treatment with acids.

In addition to the clear bits of granular calcite, there are others of similar shapes which appear dense and grayish under the microscope and remain aphanitic even when magnified more than 400 diameters; these are the bodies which appear white in the hand-specimen. On the weathered surface they stand out as porcelainous granules with pitted surfaces. The chalky material is a carbonate, probably dolomite, and the pits doubtless represent the locations of calcite grains which have been dissolved. That these opaque bodies are not intrinsically different from their more granular neighbors is indicated by the fact that the slide exhibits all gradations between the two, and in several cases both the granular and the aphanitic materials are present in the same globule.

Whether clear or opaque the oolitic bodies rarely show any trace of distinctive structure. Among the former one occasionally sees compound globules like those in No. 17,* and in a very few cases faint concentric lines are visible near the outer edges of the bodies. No trace of fossils can be seen.

* See page 381.

From this description it is obvious that the specimen has its nearest allies in the black oolite of the Ch'ang-hia limestone,* closely resembling that rock in texture and structure. It preserves, however, even fewer of the familiar characteristics of oolites, and must be considered as representing a slightly more advanced stage in the crystallization of the rock.

MESOZOIC.

The upper coal-bearing series, or red beds, of Ssï-ch'üan have been shown, by Pumpelly and Richthofen, to belong to the earlier Mesozoic. The contact with the underlying Paleozoic limestones has not yet been observed in this district, but it is undoubtedly unconformable. This series, to which we apply the name K'ui-chóu formation, is composed of weak sandy and shaly strata which are interbedded with occasional banks of limestone. The character of the rocks differs considerably in the different areas observed. Many of the rocks are reddish. As yet no igneous intrusives have been found in association with the formation in any locality.

ROCKS OF SEDIMENTARY ORIGIN.

PSEPHITES.

Black flint conglomerate, No. 147.—The exact place which this conglomerate occupies in the vertical scale is unknown. Our specimen was found in the float along the Ta-ning-ho, 7 miles, 11 kilometers, below Ta-ning-hién. The abundance of pebbles of black flint in the rock indicates that it was developed during the erosion of the flinty Wu-shan limestones. On this account there can be little doubt that it is Post-Carboniferous in age. The balance of evidence indicates that it is probably a basal conglomerate in the K'ui-chóu series.

The conglomerate is composed of rounded and subangular pebbles which have evidently been waterworn. The pebbles average less than 1 inch in diameter, although the maximum size is more than 2 inches. They are composed almost entirely of black and banded cherts with a few gray flints and bits of white vein-quartz. The matrix in which these pebbles are embedded is a firm impure sandstone of light-brown color.

The pieces of black flint are exceedingly fine-grained and appear brown rather than black in the slide. The flints are undoubtedly composed very largely of quartz, but this is so mingled with dark impurities that it is hardly possible to differentiate any of the components of the rock. In the pebbles of white quartz strain-shadows are very prominent, and on this account it is inferred that they have been derived from the Pre-Cambrian rocks, since strain effects are rarely prominent in the younger series.

* See page 381.

The sandy matrix consists largely of closely packed angular grains of quartz. The interstices between these veins are completely filled with a fine-grained granular cement of quartz, which has evidently been deposited in that situation from solution. The cement is discolored by yellowish-gray material in which limonite and minute scales of mica may be perceived. Many of the quartz grains show undulatory extinction, and some of them are crossed by fractures. Along the edges of the grains it is sometimes possible to see the first traces of granulation. Since the cement does not fill the fractures it seems probable that the mechanical deformation which these features indicate occurred at some time subsequent to the cementing of the sandstone.

CARBONATE ROCKS.

Dark fossiliferous limestone, No. 146.—This is a typical specimen of the dark limestone which overlies the red shales of the K'ui-chóu series along the lower course of the Ta-ning-ho. It was obtained 7 miles, 11 kilometers, south of Ta-ning-hién, Ssï-ch'üan.

A massive limestone of blackish-gray color. The bulk of the rock has an aphanitic texture, but glistening crystals of calcite are scattered abundantly throughout. Fragments of a Terebratuloid brachiopod are visible here and there.

Under the microscope the aphanitic portion of the rock appears as a cryptocrystalline mass of calcite darkened by indistinguishable impurities. Nebulous spots, bits of shell, specks of carbon and limonite, and even well-preserved casts of foraminifera, are distributed through this dark material.

The most prominent features of the rock are the abundant coarse crystals of calcite already mentioned. The bodies are rounded or subangular in form and vary from 0.2 to 1 mm. in diameter. In some cases distinct forms of minute shells can be seen inclosing the calcite bodies, but in the vast majority of cases the shapes are not recognizable.

This rock has obviously been but slightly altered from its original condition; as proof of this we have the preservation of such delicate shells as those of the foraminifera. On this account we can hardly suppose that the calcite globules are recrystallized oolites, as they appear to be in some of the Cambrian limestones (No. 11); and in this connection it may be observed that no traces of oolitic structures can be detected in this specimen. In many cases the calcite crystals occupy the cavernous portions of little molluscoid shells, while others are apparently crystallized bits of the shell material itself, and possibly all of them are thus connected with organic particles.

NUMERICAL TABLE OF ROCK-SPECIMENS FROM CHINA.

	Rock.	Locality.	Page.
1	Granite	Khin-gan Mts., Manchuria	358
2	Hypersthene gabbro	Tsi-nan-fu, Shan-tung	403
3	Quartz-syenite porphyry	Tsi-nan-fu, Shan-tung	397
4	Mottled limestone	Ch'au-mi-tién, Shan-tung	392
5	Conglomeratic limestone	Ch'au-mi-tién, Shan-tung	390
6	Gray limestone	Ch'au-mi-tién, Shan-tung	391
7	Gray limestone	Ch'au-mi-tién, Shan-tung	391
8	Crystalline dolomite	Ch'au-mi-tién, Shan-tung	378
9	Brown limestone	Ch'au-mi-tién, Shan-tung	391
10	Red oolite	Ch'ang-hia, Shan-tung	379
11	Gray crystalline oolite	Ch'ang-hia, Shan-tung	382
12	Micaceous sandstone	Ch'ang-hia, Shan-tung	Not described.
13	Quartz-syenite porphyry	Ch'ang-hia, Shan-tung	398
14	Red oolite	Ch'ang-hia, Shan-tung	378
15	Gray limestone	Ch'ang-hia, Shan-tung	Not described.
16	Syenite porphyry	Ch'ang-hia, Shan-tung	396
17	Black oolite	Ch'ang-hia, Shan-tung	381
18	Black oolite	Ch'ang-hia, Shan-tung	381
19	Ferruginous limestone	Ch'ang-hia, Shan-tung	392
20	Gneissoid granite	Ch'ang-hia, Shan-tung	371
21	Biotitic hornblende schist	Ch'ang-hia, Shan-tung	369
22	Biotite gneiss	Ch'ang-hia, Shan-tung	370
23	Syenite porphyry	Ch'ang-hia, Shan-tung	397
24	Basalt porphyry	T'ai-shan, Shan-tung	393
25	Biotite granite	T'ai-shan, Shan-tung	377
26	Epidote granite	T'ai-shan, Shan-tung	374
27	Biotitic hornblende schist	T'ai-shan, Shan-tung	368
28	Hornblende gneiss	T'ai-shan, Shan-tung	368
29	Biotitic hornblende gneiss	T'ai-shan, Shan-tung	367
30	Biotite gneiss	T'ai-shan, Shan-tung	365
31	Biotite granite	T'ai-shan, Shan-tung	375
32	Red gneissoid granite	T'ai-shan, Shan-tung	372
33	Biotitic granite	T'ai-shan, Shan-tung	374
34	Epidote gneiss	T'ai-shan, Shan-tung	370
35	Peridotite	Sin-t'ai-hién, Shan-tung	409
36	Contact rock	Sin-t'ai-hién, Shan-tung	Not described.
37	Red sandstone	Sin-t'ai-hién, Shan-tung	Not described.
38	Calcareous sandstone	Sin-t'ai-hién, Shan-tung	400
39	Limestone breccia	Sin-t'ai-hién, Shan-tung	399
40	Conglomeratic limestone	Sin-t'ai-hién, Shan-tung	390
41	Pink limestone	Sin-t'ai-hién, Shan-tung	400
42	Dacite porphyry	Kau-kia-p'u, Shan-tung	395
43	Altered basalt	Kau-kia-p'u, Shan-tung	394
44	Dacite porphyry	Kau-kia-p'u, Shan-tung	394
45	Conglomeratic limestone	Yen-chüang, Shan-tung	391
46	Conglomeratic limestone	Yen-chüang, Shan-tung	390
47	Conglomeratic limestone	Yen-chüang, Shan-tung	390
48	Conglomeratic limestone	Yen-chüang, Shan-tung	391
49	Augite andesite	Yen-chüang, Shan-tung	405
50	Augite andesite	Yen-chüang, Shan-tung	406
51	Sandstone	Yen-chüang, Shan-tung	400
52	Syenite porphyry	Yen-chüang, Shan-tung	403
53	Syenite porphyry	Yen-chüang, Shan-tung	402
54	Porphyritic basalt	Yen-chüang, Shan-tung	407
55	Augite-syenite porphyry	Chóu-ts'un, Shan-tung	401
56	Rhyolite porphyry	Tsing-tau, Shan-tung	411
57	Basalt	Chóu-ts'un, Shan-tung	408
58	Granite	Shĭ-san-ch'an, Liau-si	362
59	Aplite	Shĭ-san-ch'an, Liau-si	363
60	Schistose quartzite	Kau-shan-tzĭ, Liau-si	362
61	Sideritic slate	Ta-shi-kiau, Liau-tung	359
62	Quartzitic conglomerate	Fu-chóu, Liau-tung	360
63	Hornblende basalt	Fu-chóu, Liau-tung	361

NUMERICAL TABLE OF ROCK-SPECIMENS FROM CHINA.—Continued.

	Rock.	Locality.	Page.
64	Buff rhyolite	Ch'au-kia-tién, Liau-tung	361
65	Ferruginous arkose	Ch'au-kia-tién, Liau-tung	360
66	Rhyolite porphyry	Siung-yué-ch'öng, Liau-tung	361
67	Granite porphyry	T'ang-hién, Chĭ-li	417
68	Granite porphyry	T'ang-hién, Chĭ-li	418
69	Aplite	T'ang-hién, Chĭ-li	419
70	Aplite	T'ang-hién, Chĭ-li	420
71	Hornblende gneiss	T'ang-hién, Chĭ-li	414
72	Quartz-muscovite schist	T'ang-hién, Chĭ-li	416
73	Flint conglomerate	T'ang-hién, Chĭ-li	421
74	White quartzite	T'ang-hién, Chĭ-li	421
75	Amphibolite	Fou-p'ing-hién, Chĭ-li	415
76	Biotite-hornblende schist	Fou-p'ing-hién, Chĭ-li	416
77	Biotitic hornblende granite	Fou-p'ing-hién, Chĭ-li	417
78	Granite porphyry	Fou-p'ing-hién, Chĭ-li	418
79	Biotitic hornblende granite	Fou-p'ing-hién, Chĭ-li	417
80	Chlorite gneiss	Li-yuan-p'u, Chĭ li	414
81	Biotite gneiss	Li-yuan-p'u, Chĭ-li	413
82	Arkose quartzite	Shĭ-tsui, Shan-si	423
83	Augen-gneiss	Shĭ-tsui, Shan-si	433
84	Micaceous graywacke	Shĭ-tsui, Shan-si	424
85	Pink-and-green amphibolite	Shĭ-tsui, Shan-si	430
86	Biotite schist	Shĭ-tsui, Shan-si	426
87	Scapolite schist	Shĭ-tsui, Shan-si	427
88	Banded limestone	Si-ta-yang, Chĭ-li	420
89	Schistose greenstone	Shĭ-tsui, Shan-si	432
90	Amphibolite	Shĭ-tsui, Shan-si	430
91	Magnetite quartzite	Shĭ-tsui, Shan-si	424
92	Gneissic graywacke	Shĭ-tsui, Shan-si	425
93	Rhyolite porphyry	Shĭ-tsui, Shan-si	432
94	Greenstone	Shang-ho-miau, Shan-si	432
95	Garnet schist	Shang-ho-miau, Shan-si	428
96	White marble	Shang-ho-miau, Shan-si	429
97	Conglomerate schist	Shang-ho-miau, Shan-si	422
98	Gneissic arkose	Shang-ho-miau, Shan-si	425
99	Quartz-sericite schist	Shang-ho-miau, Shan-si	425
100	Banded marble	Shang-ho-miau, Shan-si	429
101	Gray phyllite	Shang-ho-miau, Shan-si	426
102	Banded marble	Shang-ho-miau, Shan-si	430
103	Chloritic muscovite gneiss	Peĭ-t'ai peak, Shan-si	434
104	Impure sandstone	Wu-t'ai-hién, Shan-si	436
105	Red dolomite	Wu-t'ai-hién, Shan-si	437
106	Arkose conglomerate	Fang-lan-chŏn, Shan-si	435
107	Arkose conglomerate	Fang-lan-chŏn, Shan-si	435
108	Hematitic sandstone	Tóu-ts'un, Shan-si	437
109	Black slate	Siau-wang-kién, Shen-si	439
110	Black limestone	Chang-k'ou-shĭ, Shen-si	Not described.
111	Green slate	Chang-k'ou-shĭ, Shen-si	438
112	Granite	Wŏn-kung-miau, Shen-si	Not described.
113	Hornblende-biotite granite	Wŏn-kung-miau, Shen-si	440
113½	Black crystalline limestone	Shĭ-ts'üan-hién, Shen-si	455
114	Quartzite gneiss	Shĭ-ts'üan-hién, Shen-si	444
115	Silvery mica schist	Shĭ-ts'üan-hién, Shen-si	453
116	Micaceous marble	Liang-ho, Shen-si	456
117	Micaceous marble	Liang-ho, Shen-si	456
118	Spotted mica schist	Liang-ho, Shen-si	452
119	Schistose limestone	Liang-ho, Shen-si	455
120	White marble	Shĭ-ts'üan-hién, Shen-si	457
121	Black limestone	Shĭ-ts'üan-hién, Shen-si	454
122	Green gneissic quartzite	Shĭ-ts'üan-hién, Shen-si	443
123	Mica schist	Shĭ-ts'üan-hién, Shen-si	451
124	Gray phyllite	Shĭ-ts'üan-hién, Shen-si	450
125	Black amphibolite	Shĭ-ts'üan-hién, Shen-si	457
126	Greenstone	Shĭ-ts'üan-hién, Shen-si	462

NUMERICAL TABLE OF ROCK-SPECIMENS FROM CHINA.—Continued.

	Rock.	Locality.	Page.
127	White aplite	Shĭ-ts'üan-hién, Shen-si	464
128	Olive-gray clay slate	Han-wang-ch'öng, Shen-si	449
129	Anthracite coal	Siau-tau-ho, Shen-si	Not described.
130	Anthracite coal	Siau-tau-ho, Shen-si	Not described.
131	Crumpled slate	Siau-tau-ho, Shen-si	447
132	Gneissic graywacke	Pa-kua-miau, Shen-si	445
133	Black argillite	Tsöng-kia-pa, Shen-si	446
134	Conglomerate schist	Tsöng-kia-pa, Shen-si	442
135	Siliceous dolomite	Pai-kiu-hia, Shen-si	454
136	Anthracite coal	Pai-kiu-hia, Shen-si	Not described.
137	Saussurite gabbro	Pai-kiu-hia, Shen-si	459
138	Pyritic black slate	Ku-niu-tu, Shen-si	446
139	Black clay slate	Chön-p'ing-hién, Shen-si	447
140	Black limestone	Chön-p'ing-hién, Shen-si	Not described.
141	Green nodular slate	Pai-kiu-hia, Shen-si	448
142	Gabbro contact	Pai-kiu-hia, Shen-si	460
143	Black oolite	Ta-miau-ssĭ, Sse-ch'uan	470
144	Green quartzite	Ta-ning-hién, Sse-ch'uan	468
145	Black limestone	Ta-ning-hién, Sse-ch'uan	Not described.
146	Fossiliferous limestone	San-shĭ-li-p'u, Sse-ch'uan	473
147	Flint conglomerate	San-shĭ-li-p'u, Sse-ch'uan	472
148	Quartz diorite	Nan-t'o, Sse-ch'uan	466
149	Sandstone	Nan-t'o, Sse-ch'uan	468
150	Sandstone	Nan-t'o, Sse-ch'uan	468
151	Black limestone	Nan-t'o, Sse-ch'uan	469
152	Gray oolite	Nan-t'o, Sse-ch'uan	471
153	Glacial shale	Nan-t'o, Sse-ch'uan	Not described.
154	Glacial pebbles	Nan-t'o, Sse-ch'uan	Not described.
155	Quartzite	Tung-yü, Shan-si	423
156	Aporhyolite	Chang-p'ing-chóu, Chĭ-li	363
157	Conglomeratic limestone	Po-shan-hién, Shan-tung	391
158	Scapolite-staurolite schist	Fang-lan, Shan-si	427

RÉSUMÉ OF LITERATURE CONTAINING DESCRIPTIONS OF THE ROCKS OF CHINA.

Although several geologists have made extensive journeys in China and have even brought home collections of rock specimens, very little study of a detailed nature seems to have been made of the rocks of the Empire. In most of the reports of such expeditions, the rocks are merely referred to by name or are described in a brief way from examination of specimens in the field. The microscope has been used in only a few cases. In the following list of reports dealing with Chinese rocks, the author enumerates all of the publications containing even brief descriptions of Chinese rocks, which have come to his notice.

1867.*

Pumpelly, R.: Smithsonian Contributions to Knowledge, vol. xv, Geological Researches in China, Mongolia, and Japan, 1862-1866.

The author describes a variety of rocks from the gorges and lower valley of the Yang-tzĭ river and from the district northwest of Peking. The descriptions are as complete as could well be made before the days of the petrographical microscope.

1872.

David, Armand: Journal de mon 3me voyage d'exploration dans l'empire Chinois, Paris, 1872.

Although Père David laid small claim to being a geologist, the story of his travels from Peking southwestward across the Tsin-ling mountains to Han-chung-fu, and thence by boat down the canyons of the Han river, contains many detailed observations upon the rocks which he saw. The Abbé appears to have made no collection of specimens and the names he gives are, therefore, based entirely on inspection in the field.

1880.

Pabst, Wilhelm: Untersuchung von Chinesischen und Japanischen zur Porzellanfabrication verwandten Gesteinsvorkommnissen. Zeitschrift der Deutsch. Geol. Gesel. 1880, pp. 223-244.

This paper describes a series of 18 specimens which were collected by Richthofen in China. The majority of them are materials used in the manufacture of porcelain in the province of Kiang-si, together with certain more or less decomposed rocks which are associated with them.

1882.

Richthofen, Ferdinand von: China; Ergebnisse einiger Reise und darauf gegründeter Studien, vol. II.

The researches of Baron von Richthofen were the most extensive which have yet been attempted in China. He describes rocks from a wide range of localities. The greater number of them have been named simply from field observations. His report contains no petrographic descriptions of a detailed character.

* Dates refer to the publication of the report and not to the travels described.

1890–1893.

Lóczy, Ludwig von: Die wissenschaftliche Ergebnisse der Reise des Grafen Béla Széchenyi in Ostasien. 1877–1880. Vol. I, part 3. (First edition in Hungarian, 1890.)

In setting forth the results of his extensive geologic explorations in China, Mongolia, and Burma, Herr Lóczy names and briefly describes rocks from many localities. Detailed petrographic descriptions of a number of these were afterwards prepared by Dr. A. Koch, as mentioned below.

1895.

Steuer, A.: Mittheilungen über Gesteine aus den Chinesischen provinzen Kansu, Schensi, Hupe, und Honan. Neues Jahrbuch für Min., Geol., und Pal. 1895, x.

The author gives a brief description, based on microscopical study, of seventy-three rocks collected in the northwestern part of China by Herr Michaelis. Very little mention is made in this paper of the geological occurrence of the rocks and their relationships to each other.

1899.

Koch, Anton: Die wissenschaftliche Ergebnisse der Reise des Grafen Béla Széchenyi in Ostasien, 1877–1880.

In this report (Vol. III), Dr. Koch describes the more important types of rocks collected by Herr Ludwig Lóczy, in the provinces of Hu-pei, Shen-si, Kan-su, Kokonor, and Ssï-ch'uan. The descriptions are rather brief and are usually generalized from several specimens. Little information is given regarding the geologic relations of the rocks in the field. The report enumerates 152 specimens, but a much smaller number has been actually described. Nevertheless, the fact that modern microscopical methods have been used, renders this one of the most valuable contributions yet made to our knowledge of the rocks of China.

Lórenthey, E.: Same report, III.

A number of specimens of limestones are described, special attention being given to the fossil foraminifera contained in them.

1901.

Vogelsang, Karl: Petermann's Mittheilungen, 1901, pp. 241–250.

This report on several journeys in northern and central China contains only brief characterizations of the various rocks observed.

1904.

Vogelsang, Karl: Petermann's Mittheilungen, 1904, p. 11, et seq.

The writer gives an account of a journey made in 1900, north, west, and south from I-chang-fu in Hu-pei by way of Chu-chï-hién, the Nan-kiang, and the Ta-ning-ho to Wu-shan on the Yang-tzï. He names the rocks observed *en route* and describes a few of them briefly on the basis of microscopic study.

1905.

Lorenz, Theo.: Beiträge zur Geologie und Palæontologie von Ostasien, Marburg, Teil I.

This paper describes the geology of portions of the province of Shan-tung and incidentally it contains brief descriptions of several igneous and metamorphic rocks from that province. The author discusses at somewhat greater length the origin of the peculiar oolitic and conglomeratic limestones of the Cambrian terranes.

PLATE LIV.

STRAIN PHENOMENA IN FELDSPARS.

A. Microcline and vein-structure in feldspar. The minerals of the slide are chiefly quartz and feldspar. Near the center a quadratic crystal of orthoclase exhibits microcline grating on the lower side and a set of gash-veins on the upper. Both are regarded as effects of distortion of the rock during metamorphism. (Biotitic granite from the Archean complex in the T'ai-shan, Shan-tung. Specimen 33, crossed nicols, × 52, page 374.)

B. Gash-veins in feldspar. Most of the field is occupied by a large crystal of orthoclase which incloses a slightly decayed body of orthoclase. Locally microcline grating may be observed in the orthoclase—the areas which possess this structure having no definite boundaries. The wavy white streaks are vein-like bodies of a sodic feldspar which appears to fill cracks in the orthoclase. Along the right-hand edge of the crystal these veins may be seen to coalesce with the white albite cement which has developed in consequence of the granulation and recrystallization of a portion of the rock. (Red gneissoid granite from the Archean complex in the T'ai-shan, Shan-tung. Specimen 32, crossed nicols, × 40, page 372.)

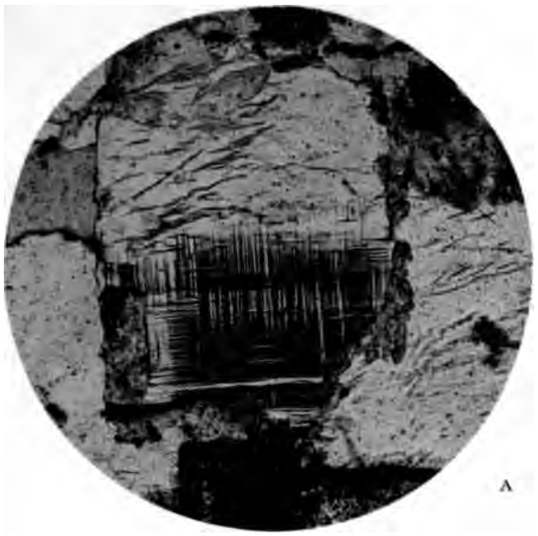
C. Gash-vein structure in feldspar. A large orthoclase crystal crossed by two intersecting sets of gash-veins which are filled with a feldspar of slightly different optical properties. The veins are believed to be the filling of cracks developed by torsional strains in the feldspar. (Dark biotite-granite from the Archean complex in the T'ai-shan, Shan-tung. Specimen 31, crossed nicols, × 55, page 375.)

LIMESTONES FROM SHAN-TUNG.

D. Conglomeratic limestone, showing the end of one of the pebbles highly magnified. The dark pebble on the left is minutely crystalline and contains abundant ferruginous impurities. The matrix on the right is clear crystalline calcite. The normal margin of the pebble represents the smoothly worn original surface; the edge seen in this slide has been corroded and is indented by calcite crystals of the ground-mass. (Conglomeratic limestone from the Upper Cambrian near Yen-chuang, Shan-tung. Specimen 47, ordinary light, × 90, page 384.)

E. Shell nucleus in red oolite. The dark oolitic bodies show the concentric structure typical of such rocks. The nucleus of the largest body is a bit of shell of some invertebrate. The matrix of the rock is clear granular calcite and the fractures which traverse the slide are filled with the same mineral. (Red oolite from the Man-t'o formation near Ch'ang-hia, Shan-tung. Specimen 14, ordinary light, × 20, page 378.)

F. An oolitic body containing a fragment of an older body of the same character. In both nucleus and enveloping crust, the concentric and radiate structures are clearly visible. The dark streaks are amorphous hematite. It will be noted that the radiate structure is more prominent on the convex than on the flat side of the nodule, suggesting that the structure may be due to radial cracks produced by expansion from within. (Red oolite from Ch'ang-hia, Shan-tung. Specimen 10, ordinary light, × 50, page 379.)



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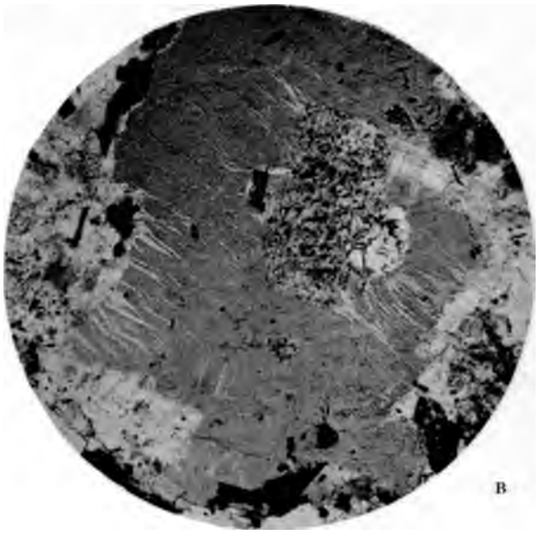

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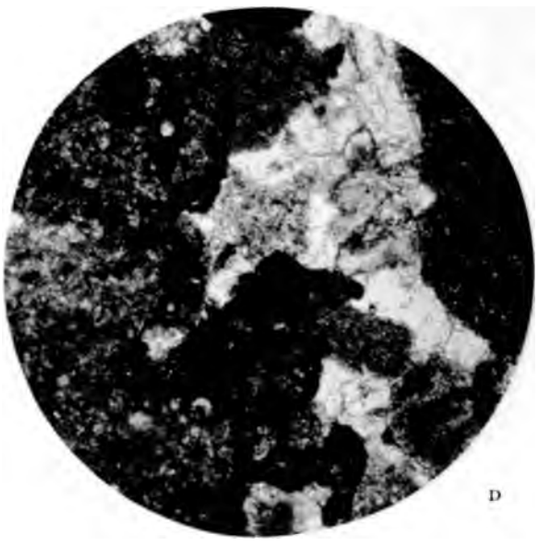

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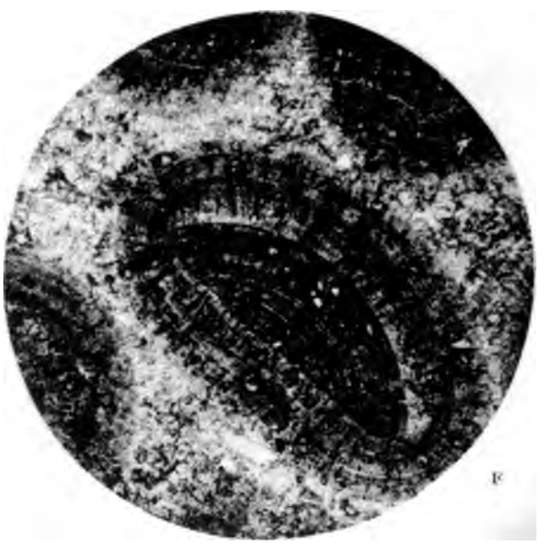

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PLATE LV.

OOLITES AND BASALT FROM SHAN-TUNG.

A. Girvanella (?) tubes in oolite. This shows an oolitic body with the usual concentric and radial structures inclosing an elongate bundle of tubules which have been described as algæ and given the name Girvanella. (Red oolite from the Lower Cambrian near Ch'ang-hia, Shan-tung. Specimen 10, ordinary light, × 70, page 379.)

B. An oolitic body which does not show the usual concentric or radial structures. The light spots are calcite, while the dark part is amorphous hematite. It is thought that the granular texture of this section has been caused by the crystallization of the carbonate and that during the process the ferruginous impurities were relegated to the boundaries between the calcite grains, thus destroying the original concentric structure and developing in its place a net-work of hematite. The matrix in which the bodies are embedded consists of calcite darkened with earthy iron ores and containing a few small flakes of mica. (Same as last, ordinary light, × 50, page 379.)

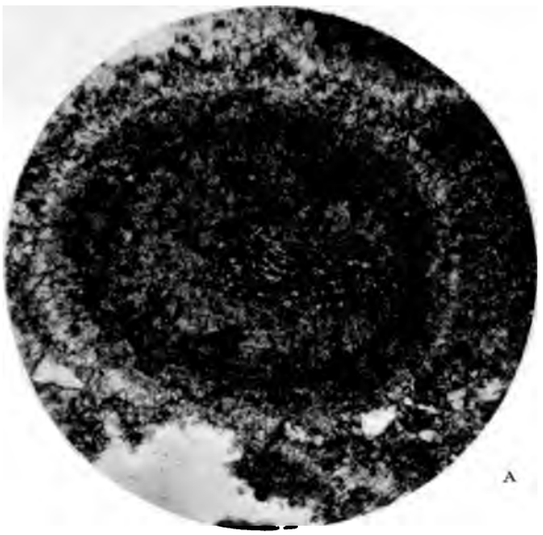
C. Slightly altered oolite. The dark circular sections of oolitic bodies show minutely crystalline calcite darkened by finely divided carbonaceous matter. They are surrounded by radiate fringes of calcite and are embedded in a clear granular matrix of the same mineral. The advance of crystallization has sufficed only to obscure the nuclei and to dim the concentric banding. Compare with Plates LIV, E and F, and LV, D and E, for less altered and more altered phases. (Black oolitic limestone from the Cambrian near Ta-miau-ssi, Ssi-ch'uan. Specimen 143, ordinary light, × 20, page 470.)

D. Granular oolite. This section represents a stage intermediate between that depicted in C and E. The calcite of both matrix and corpuscles is rather coarsely crystalline. The nuclei of the oolitic bodies are entirely obsolete, but a trace of the concentric banding is still preserved by the circular streaks of dark impurities which pass indiscriminately through the more recently formed crystals of the carbonate. The slide shows the peculiar oblong shape and rude tangential orientation of many of the calcite crystals. (Black and gray oolite typical of the Ch'ang-hia formation near the village of that name, Shan-tung. Specimen 18, ordinary light, × 48, page 381.)

E. Crystallized oolite. The dull ground-mass consists of fine-grained calcite, as in ordinary limestone. The round bodies are oolitic nodules which have completely crystallized. The parallel cleavage serves to show that several of them consist of a single crystal, which, however, retains the outline of the original nodule. This figure should be compared with preceding sections. In the present slide the traces of concentric structure are obliterated. (Oolitic limestone from the Middle Cambrian near Ch'ang-hia, Shan-tung. Specimen 11, slide (*a*), ordinary light, × 20, page 382.)

F. Porphyritic basalt. The dark ground-mass is composed of feldspar, augite, and iron ores, in particles of all shapes and sizes. The crystals bordered with black near the center of the field are olivine partly altered to serpentine. Just above this and to the left there is a basal section of pyroxene. The clear phenocrysts are labradorite. In the largest of these, minute inclusions are arranged in a zone parallel to the outline of the crystal. (Basalt from Post-Carboniferous strata near Yen-chuang, Shan-tung. Specimen 54, polarized light, × 50, page 407.)

RESEARCH IN CHINA.



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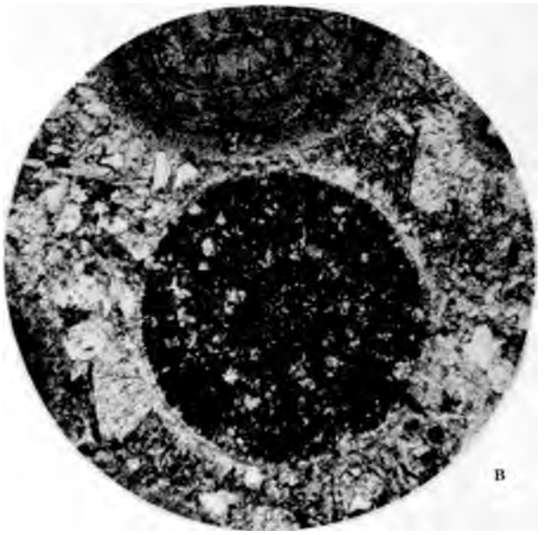

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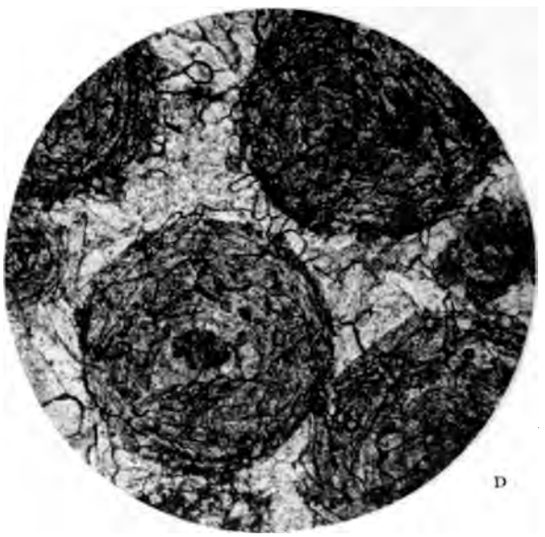

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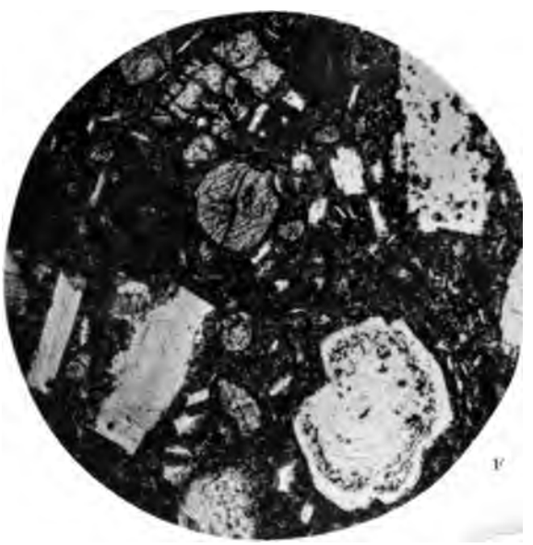

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PLATE LVI.

PRE-CAMBRIAN GNEISSES.

A. Bent feldspar in gneiss. The left side of the field is crossed by a shear-zone in which the quartz and feldspar have been crushed and dragged out into streaks. The large striated crystal of plagioclase is undisturbed except where it comes into contact with this shear-zone; there the twinning bands are bent, and the bent portion does not extinguish with the rest of the crystal. (Gneiss in the T'ai-shan complex, near T'ang-hién, Chï-li. Specimen 71, slide (*c*) crossed nicols, × 50, page 414.)

B. Rutile in altered biotite. The dark crystal occupying the center of the field is a flake of biotite surrounded by feldspar and quartz. The darker bands in the mica are unaltered biotite, while the lighter streaks indicate the extent to which the alteration to chlorite has progressed. The numerous little prisms embedded in this chlorite are rutile, which has probably been produced from the titanium content of the original biotite. (Gneissoid quartz-diorite from the Pre-Cambrian at Nan-t'o, Hu-peï. Specimen 148, slide (*a*), polarized light, × 65, page 466.)

SEDIMENTARY ROCKS FROM WEST CHÏ-LI.

C. Flint-conglomerate. The minutely crystalline portion on the right of the figure is part of a pebble of black flint. This was embedded in rounded sand-grains of quartz, several of which appear on the left. The grains and the pebbles are completely cemented by cherty silica which is identical with that of the flint pebble. (Conglomerate probably at the base of the Cambrian near Nan-t'ang-mei, Chï-li. Specimen 73, crossed nicols, × 50, page 421.)

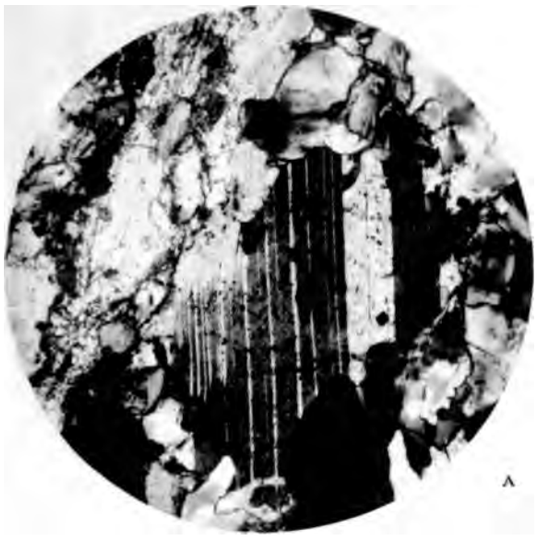
D. Banded gray limestone. The bands of dark and light color are due to the presence of exceedingly minute carbonaceous impurities which appear to have been distributed in layers in the original calcareous mud. The material has since crystallized, but the color bands have not been affected by the growth of the crystals, for they pass through them without deviation. (Typical phase of the Ta-yang limestone at Ta-yang, Chï-li. Specimen 88, ordinary light, × 55, page 420.)

ROCKS OF THE WU-T'AI SYSTEM.

E. Magnetite-quartzite. The clear interlocking crystals of quartz probably represent sand-grains and cement which have entirely recrystallized. The black spots are idiomorphic crystals of magnetite which doubtless have been derived from ferruginous impurities in the original sandstone. The upper part of the field is crossed by a vein of magnetite which is of later age. The cloudy translucent bodies in this vein and scattered through the slide are siderite, now partly altered to iron oxide. (A thick member of the Shï-tsui series northwest of Shï-tsui. Specimen 91, ordinary light, × 40, page 424.)

F. Garnet-schist. Two small garnets and several biotite flakes are embedded in a biotitic schist in which the micas have a distinct parallel arrangement. In the vicinity of the large crystals the micaceous bands are bent and thus form eye-spots resembling those in conglomerate-schists. (Garnet-staurolite-schist associated with white marble in the Shang-ho-miau section, Shan-si. Specimen 95, slide (*a*) ordinary light, × 20, page 428.)

RESEARCH IN CHINA.



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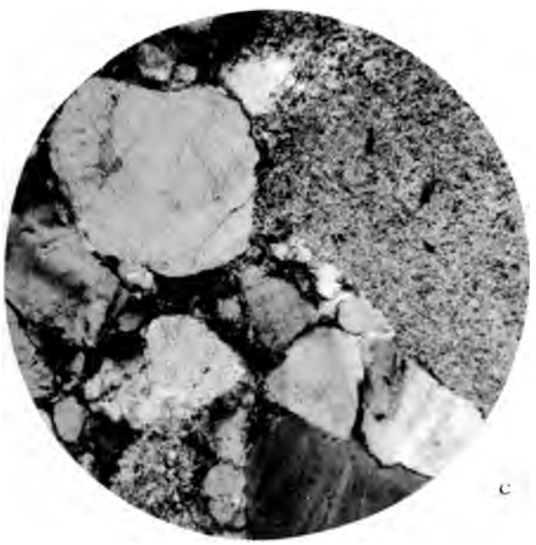

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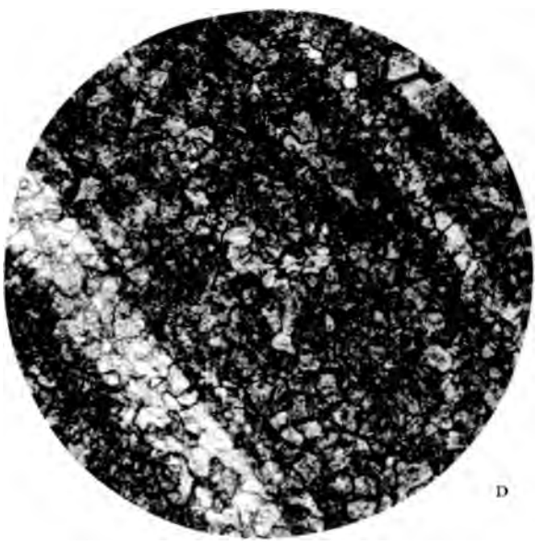

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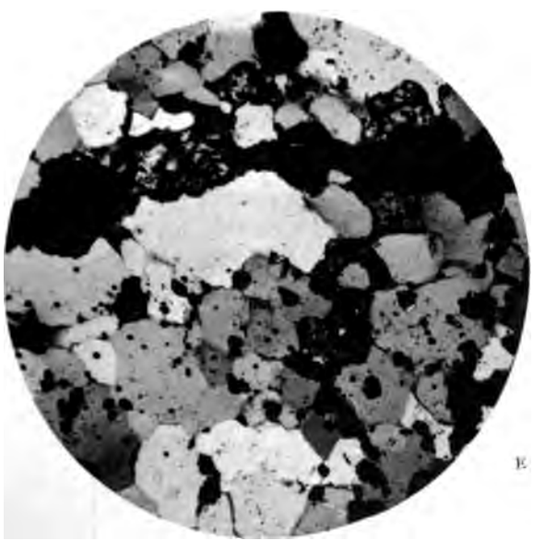

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PLATE LVII.

AMPHIBOLITES IN THE WU-T'AI SYSTEM.

A. Calcareous amphibolite. The upper portion of the field consists of matted fibers of actinolite. The lighter part below shows quartz, feldspar, and calcite. Near the middle of the figure large biotite flakes have developed since the formation of the actinolite and have absorbed needles of the latter without disturbing their parallel arrangement. (Near the base of the Shï-tsui series, 4 miles south of Shï-tsui, Shan-si. Specimen 85, slide (*b*), polarized light, × 25, page 430.)

B. Gneissic amphibolite. The light-colored field is a mosaic of quartz and feldspar. Little dark flakes of biotite mark the horizontal trend of the gneissic bands. A large porphyritic crystal of hornblende on the right includes portions of the banded groundmass in which it has grown. (A member of the Shï-tsui series, 3 miles northwest of Shï-tsui. Specimen 90, slide (*b*), polarized light, × 20, page 431.)

ROCKS OF THE HAN SYSTEM.

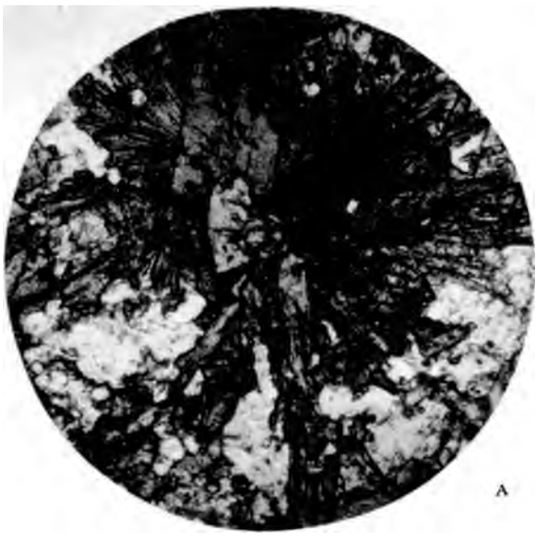
C. Gneissic graywacke, showing unreduced bodies of feldspar in eye-spots surrounded by the schistose matrix of the rock. The light streaks are quartz and feldspar, and the dark areas chiefly biotite. (Schists near Pa-kua-miau, Shen-si, probably of the K'ui-chóu formation. Specimen 132, slide (*b*), polarized light, × 27, page 445.)

D. Soft greenish slate. Section is transverse to the cleavage and shows numerous unreduced grains of quartz deformed into lenticular bodies. Some of them have been sliced diagonally in the process of deformation. (Paleozoic slates, probably representing the Sin-t'an formation, at Han-wang-ch'öng, Shen-si. Specimen 128, slide (*b*), polarized light, × 50, page 449.)

E. Crumpled black slate. The finely crystalline mass of quartz and graphitic matter has been intensely contorted, as shown by the wavy black streaks. In some cases the folds pass over into microscopic overthrusts. (Coal-bearing slates of the Wu-shan formation at Siau-tau-ho, Shen-si. Specimen 131, slide (*a*), ordinary light, × 17, page 447.)

F. Mica-schist. Large ragged flakes of biotite inclosed in a schistose mass of quartz, feldspar, and muscovite. The biotites are younger than the schistosity and occlude portions of the mica streaks which they have absorbed during their growth. (Late Paleozoic schists, Shï-ts'üan-hién, Shen-si. Specimen 115, slide (*b*), polarized light, × 45, page 453.)

RESEARCH IN CHINA.



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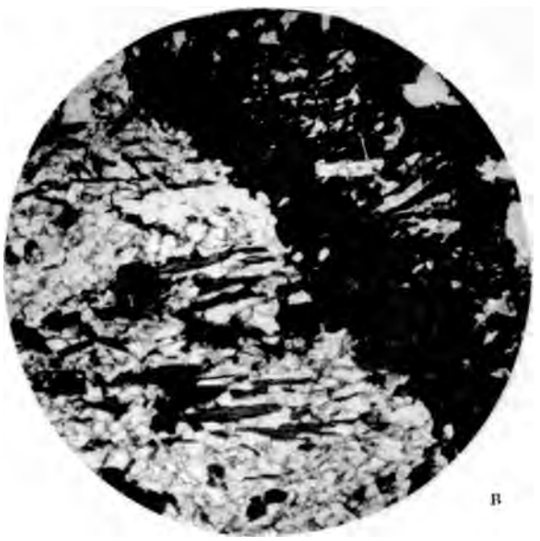

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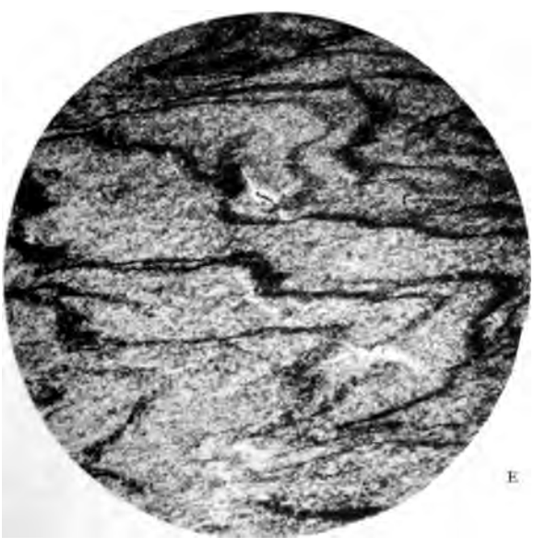

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SECTION V

ZOOLOGY

BY

ELIOT BLACKWELDER

CHAPTER XVII.

REPORT ON ZOOLOGY.

By Eliot Blackwelder.

INTRODUCTION.

The studies upon which the report is based were made in the course of (*a*) a journey from Tientsin southward into central Shan-tung, and thence eastward to the German port of Tsingtau: (*b*) a short trip in southwestern Liau-tung between Niu-chuang and Port Adams; and (*c*) the long march from Pau-ting-fu, in Chï-li, west and southwest through Shan-si and southern Shen-si to the Yang-tzï-kiang at Wu-shan. Much the largest part of the work was done in the last of these journeys. Brief observations were also made along the Trans-Siberian railway. The zoological data which were assembled by the writer in the course of this work consist of seventy-five specimens of vertebrates representing fifty-six species, a daily record of all birds and mammals seen, a series of more or less complete descriptions of birds as seen in the field, and numerous notes as to habits, food, and other characteristics of various animals.*

My hearty thanks are due to Dr. C. W. Richmond, Dr. Leonhard Stejneger and Mr. Gerrit S. Miller, of the U. S. National Museum, for their generous aid in studying the specimens and descriptions of many of the species mentioned in the following pages. I wish also to acknowledge the sympathy and broad-minded attitude of the chief of the expedition, Mr. Bailey Willis, whose interest greatly facilitated the work in the field.

CLASS AMPHIBIA.

ORDER ANURA. (*Frogs, toads, etc.*)

Hyla chinensis Guenther.

Guenther: Catalogue of Batrachia salientia in British Mus., 1858, p. 108, plate IX, fig. C.

A small company of these bright green frogs was found in a shallow temporary pool of water, on the grassy surface of a mountain ridge (6,000 feet, 1,800 meters, elevation). The chorus made by them was so loud as to be plainly audible at a distance of 2,000 feet, 600 meters.

Specimen No. 6055. North slope of the Ts'in-ling mountains (Lung-t'an-ssï) in southern Shen-si, April 26, 1904.

Bufo sp. (?).

Very young dark-brown toads, presumably of this genus, were abundant in damp grain-fields near Hing-an-fu, Shen-si, in the middle of May. Those seen averaged 1.7 centimeters in length.

*The collection of 448 beetles secured by the writer has been presented to the U. S. National Museum, with the understanding that it be described in some forthcoming publication of the museum. The beetles will not, therefore, be discussed in this report.

CLASS REPTILIA.

Few reptiles were seen outside of the provinces of Shen-si and Ssï-ch'uan, for the reason that we visited other parts of the empire only during the winter season. In the mountainous district of southern Shen-si and east Ssï-ch'uan small lizards were often very abundant. Snakes were apparently much less numerous. This reptilian fauna has its closest relationships with that of upper India and Burmah, rather than with southeastern China. The single lizard from Shan-tung, on the other hand, is of a species which is already known to exist in Japan and has not yet been reported from the western provinces of China.

The specimens of reptiles and batrachians have been studied and identified by Dr. Leonhard Stejneger, of Washington, D. C.

SUBORDER LACERTILIA. (*Lizards, etc.*)

Japalura yunnanensis ANDERSON.

ANDERSON: Zoology of West Yûn-nan (British Govt. Rep.), p. 803, plate LXXVII.

This handsome bright-colored lizard is abundant in the mountains of southern Shen-si, and thence southward to the Yang-tzï river and beyond. It frequents the steep, sunny slopes of the canyons, especially where scanty herbage grows in the waste slopes of soil and loose rock. Many are startled by the traveler as he walks along the trail. They are swift of movement, but are not so timid as to run more than a few feet before stopping to see if they are being pursued. The young of this species lack the tubercled scales and the high degree of ornamentation seen in the adult.

Specimen No. 6073,* adult; head waters of the Ta-ning-ho, E. Ssï-ch'uan (3,000 feet, 900 meters, elevation), May 29, 1904.

Specimen No. 6075, adult; Nan-t'ou on the Yang-tzï, W. Hu-peï, June 8, 1904.

Specimen No. 6066, juv.; Ta-ho-pa on the P'u-ho, southern slope of the Ts'in-ling mountains, Shen-si, May 7, 1904.

Hinulia indica GRAY.

GRAY: Ann. Mag. of Nat. History, 2d ser., vol. XII, 1853, p. 388.

A dull-colored species common in the basin of the Han river, in southern Shen-si. Its habits and habitat are similar to those of the last-named species, and the two were usually found associated.

Specimen No. 6070, canyon of Han-kiang, near Shï-ts'üan-hién, Shen-si, May 11, 1904.

Takydromus septentrionalis GUENTHER.

GUENTHER: Reptiles of British India, 1864, p. 70, plate VIII, fig. E.

This species was frequently seen in the Ts'in-ling mountains, mostly south of the watershed. Stony slopes clad with sparse grass and brush appear to be their favorite haunts. The adult and young stages are dissimilar in coloration, the former being striped, while the latter is devoid of conspicuous markings.

A small lizard, which is referred to this species with considerable doubt, is abundant during the autumn upon the stony slopes of the mountains in central Shan-tung. It is dull brownish in color, slender and very agile. It did not disappear until late in November after repeated light frosts had occurred.

*These numbers are the original field numbers of the specimens.

Specimen No. 6601, juv.; Siau-wang-kién, Shen-si; north slope of the Ts'in-ling mountains (3,500 feet, 1,050 meters, elevation), May 1, 1903.

Specimen No. 6067, adult; Ta-ho-pa, valley of the P'u-ho, on the south slope of the Ts'in-ling mountains, Shen-si, (1,500 feet, 450 meters, elevation).

Gecko japonicus (DUMÉRIL & BIBRON).

DUMÉRIL & BIBRON: Erpétologie générale, III, 1836, p. 337.

A single specimen of this species was found beneath a sheet of canvas which had been spread upon the damp earthen floor of a Chinese inn, at Hua-ma-wan, in central Shan-tung. It was sluggish in movement. The Chinese fear these geckos as if they were venomous or otherwise harmful.

Specimen No. 6016; Hua-ma-wan, central Shan-tung, November 13, 1903.

SUBORDER OPHIDIA. (*Snakes, etc.*)

Polyodontophis collaris (GRAY).

GRAY: Ann. Mag. of Nat. History, 2d ser., vol. XII, 1853, p. 390.

Several individuals were seen along the road through the basin of the Han-kiang in southern Shen-si. The species appears to have a habitat similar to that of the lizards *Takydromus* and *Japalura*. It is a slender, active serpent, marked with yellow and white bands upon a chocolate-colored background.

Specimen No. 6071, adult; Shï-ts'üan-hién, southern Shen-si, valley of the Han river.

CLASS AVES.

The opportunity to observe and collect birds was much better than that afforded by the other classes of animals. A large number of species pass the winter even in northern China, and so the ornithological work of the party did not cease with the advent of cold weather. The exigencies of travel, however, were such that only small specimens could be carried, and the time of the zoologist was often occupied with his geological duties at the very period when work on the birds might have been carried on to the most advantage.

The collection contains 64 birds, representing 49 species.* It was supplemented by descriptions of 81 additional species, individuals of which were examined in the hand or seen at short range and described at the time of observation. Regarding some of the latter there is necessarily more or less doubt. Dr. Charles W. Richmond, of the United States National Museum, has kindly studied and identified the specimens. He has also undertaken the task of identifying the written descriptions, so far as that was possible. For these gratuitous services and many helpful suggestions the writer desires to thank Dr. Richmond most cordially.

*The specimens themselves are now deposited in the U. S. National Museum, at Washington, D. C.

ANNOTATED LIST OF BIRDS.

COLYMBIDÆ.

Colymbus ruficollis PALLAS. *Little Grebe.*

Colymbus ruficollis PALLAS: Vroeg's Catal., 1764, Adumbr., p. 6 (Holland).

Observed in September, along the marshy borders of the Sungari river in Manchuria, at the point where it is crossed by the Port Arthur branch of the Chinese-Eastern railway.

ARDEIDÆ.

Ardea cinerea LINNÆUS. *Gray Heron.*

Ardea cinerea LINNÆUS: Syst. Nat., ed. 10, 1, 1758, 143 (Sweden).

Much the commonest heron in north China. During the warmer months it was seen in central Manchuria, and thence southwest as far as southern Shen-si and the Yang-tzï river. It appears to winter in suitable places throughout most of this range, for it was observed, in January, in the mountains west of Pau-ting-fu. The gray herons are usually found singly in marshes or along streams.

(?) Herodias timoriensis (LESSON). *Timor Egret.*

Ardea timoriensis LESSON: Traité d'Orn., 1831, 575 (Timor).

A small white heron, probably of this species, was rather common in the marshes of the Weï valley in Shen-si. It is possible that the bird seen was *Mesophoyx intermedia* Wagler, which differs from the Timor egret only in having an occipital crest.

Butorides javanica (HORSFIELD). *Oriental Green Heron.*

Ardea javanica HORSFIELD: Trans. of the Linnean Soc. of London, XIII, Part 1, p. 190, 1821 (Java).

A rather common bird in the mountain valleys of southern Shen-si. It frequents the terraced rice-fields particularly. It closely resembles the American *B. virescens* in its actions and silent manner.

Ardetta sinensis (GMELIN). *Yellow Bittern.*

Ardea sinensis GMELIN: Syst. Nat., 1, 642; 1788 (China).

The yellow bittern was met with only in the valley of the Han river and its tributaries, in southern Shen-si. Like its congeners, it frequents marshy localities and, in this region, the rice-fields. Most of the least bitterns are birds of retiring disposition, seldom flying unless disturbed; but the present species is often seen in flight like any other heron.

CICONIIDÆ.

Ciconia nigra (LINNÆUS). *Black Stork.*

Ardea nigra LINNÆUS: Syst. Nat., ed. 10, 1, 142, 1758 (Sweden).

The black stork appears to have a wide distribution in northern China, during all seasons of the year. We found it in Shan-tung, in November, in the mountains west of Peking in January, and in the Weï valley of Shen-si in March. It goes in small flocks which follow the larger rivers, as a rule. It is not uncommon to see a small company of these storks half asleep on a sand-bar, each one standing on one leg and as motionless as a statue. When the bird flies the white under parts are very conspicuous.

Pseudotantalus leucocephalus (PENNANT). *Painted Stork.*

Tantalus leucocephalus PENNANT: Indian Zoology, XI, plate 10, 1769 (India or Ceylon).

A small company of these birds was observed on the lower course of the Ta-ning-ho, in eastern Ssï-ch'uan, early in June.

IBIDIDÆ.

Nipponia nippon (TEMMINCK). *Japanese Ibis.*

Ibis nippon TEMMINCK: Pl. Col. V. (livr. 93), plate 551, 1835 (Japan).

The red-faced ibis is one of the commonest birds of the Weï-ho valley, in Shen-si. In the spring they may be seen, singly or in pairs, stalking over the newly plowed and irrigated fields. They make their nests in the large poplar trees in and around the numerous villages. At Lin-tung-hién two of these nests were seen in a tree inside of the walled city. The species was also observed in the more open parts of the valley of the Han river, during the month of May.

PLATALEIDÆ.

(?) **Platalea leucorodia** LINNÆUS. *Spoonbill.*

Platalea leucorodia LINNÆUS: Syst. Nat., ed. 10, 1, 139, 1758 (Sweden).

The spoonbill was seen in company with the ibises, in the valley of the Weï-ho, early in April. It is rather less common, however, and is seldom seen away from marshes or rivers. (It is possible that the birds we observed belonged to the smaller species, *P. minor*.)

ANATIDÆ.

Merganser merganser (LINNÆUS). *Goosander.*

Mergus merganser LINNÆUS: Syst. Nat., ed. 10, 1, 129, 1758 (Sweden).

A common species, during the winter, on the swift mountain rivers of western Chï-li and central Shan-si. Also observed in the valley of the Weï-ho, during March.

Anas boschas LINNÆUS. *Mallard.*

Anas boschas LINNÆUS: Syst. Nat., ed. 10, 1, 127, 1758 (Sweden).

This duck is rather common during the winter, on the open rivers of western Chï-li.

Querquedula querquedula (LINNÆUS). *Gargany Teal.*

Anas querquedula LINNÆUS: Syst. Nat., ed. 10, 1, 126, 1758 (Sweden).

Although this teal is doubtless common in the Chinese empire we observed it at only one locality, *i. e.*, along the grand canal, during the month of October.

Nettion crecca (LINNÆUS). *Common Teal.*

Anas crecca LINNÆUS: Syst. Nat., ed. 10, 1, 126, 1758 (Sweden).

We found this a common species along the rivers of southern Shan-si, the Weï valley and in the Ts'in-ling mountains. In the last locality it undoubtedly nests, for single pairs were frequently observed along the mountain streams on both sides of the divide.

Spatula clypeata (LINNÆUS). *Shoveler.*

Anas clypeata LINNÆUS: Syst. Nat., ed. 10, 1, 124, 1758 (Sweden).

A small company of these ducks were seen during the latter part of March, on the Huang-ho near Tung-kuan.

Casarca ferruginea (PALLAS). *Ruddy Sheldrake.*

Anas ferruginea PALLAS: Vroeg's Catal., 1764, Adumbr., p. 5 ("Tartary").

The commonest of the water-fowl, in northern China, during the winter. Flocks of considerable size were observed along the small sandy rivers, in central Shan-tung, in November and on the Sha-ho, west of Pau-ting-fu, in January. Large numbers were also seen in the valley of the Weï-ho during April. In eastern China this bird is not easily approached and doubtless its wariness is due to the zeal with which all water-fowl are hunted by both foreigners and natives along the coast. In the western part of the country, however, the birds may be seen walking over freshly plowed fields, following the farmer's plow and apparently undisturbed by passers-by. The inhabitants of this region evidently make no attempt to kill the birds.

RALLIDÆ.

Gallinula chloropus (LINNÆUS). *Moorhen.*

Fulica chloropus LINNÆUS: Syst. Nat., ed. 10, I, p. 152, 1758 ("Europa").

The moorhen was observed, in September, on the marshes of the Sungari, and also in the swampy "bottom-lands" along the Huang-ho, in Shan-tung. A similar bird, not positively identified, was found at the great bend of the Huang-ho, in March.

Amaurornis phœnicurus (PENNANT). *White-breasted Water-hen.*

Gallinula phœnicurus PENNANT: Indian Zoology, 1769, p. 10, plate 9 (India or Ceylon).

A single individual of this species was seen in southern Shen-si. It was walking leisurely over the half-flooded rice-fields in one of the numerous mountain valleys north of the Han river.

GRUIDÆ.

Grus grus (LINNÆUS). *Gray Crane.*

Ardea grus LINNÆUS: Syst. Nat., ed. 10, I, 141, 1758 (Sweden).

Several small flocks of these cranes were observed on the plains of central Shan-si, during March.

OTIDIDÆ.

Otis dybowskii TACZANOWSKI. *Eastern Great Bustard.*

Otis dybowskii TACZANOWSKI: Journ. für Orn., 1874, 331 (Dauria).

Bustards are still very common in the less densely populated portions of China, wherever there is sufficient open ground or plain. We saw them rarely in central Shan-tung and in the foothills west of Pau-ting-fu. They were observed in much larger numbers and more frequently in the uncultivated river flats of central Shan-si, particularly in the Hin-chóu basin. If approached while feeding, the birds raise their heads and all stand motionless facing the intruder; if pressed farther they begin to walk quickly in the opposite direction and finally take flight in a body.

CHARADRIIDÆ.

Microsarcops cinereus (BLYTH). *Gray-headed Lapwing.*

Pluvianus cinereus BLYTH: Journal Asiatic Soc. of Bengal, XI, 587, 1842 (Calcutta).

This large plover we saw along the lower course of the Fön-ho in Shan-si, during the month of March. In the next few weeks it was very common on the plain about Sian-fu. Single birds or pairs frequent the cultivated fields and dry stream courses, with much the same habits as our upland plover (*Bartramia longicauda*) of the United States. The note of this bird differs decidedly from the whistle-like calls of most of the plovers; it is loud and has almost a metallic ring. Judging from the anxiety displayed by the birds in those situations, we inferred that the nests are frequently placed in the dry bottoms of temporary water-courses.

Ægialitis dubia (SCOPOLI). *Little Ringed Plover.*

Charadrius dubius SCOPOLI: Del. Floræ et Faunæ Insubr. II, 93, 1786 (Luzon).

This form was distinguished only in the valley of the Weï river, and along the tributaries which rise in the mountains to the south. During the month of April, these small plovers appear frequently, either singly or in small flocks, always resorting to the sandy banks of the rivers.

Specimen No. 6040. Collected April 13, 1904, on the sandy bank of the Weï-ho, near Chu-chï-hién, Shen-si.

Ægialitis placida (GRAY). *Long-billed ringed Plover.*

Charadrius placidus GRAY: Catal. of Mam., Birds, etc., Nepal. ed. II, 70, 1863 (Nepal).

One specimen of this bird was taken in the mountains west of Pau-ting-fu, in January, and other individuals were seen in this region. It is more than likely that the small plovers which we saw in central Shan-tung late in October, belong to the same species. Their habits are essentially like those of the preceding form.

Specimen No. 6023. Collected January 21, along the sandy bed of a mountain brook near Fóu-p'ing-hién, Chï-li.

SCOLOPACIDÆ.

Helodromas ochropus (LINNÆUS). *Green Sandpiper.*

Tringa ochropus LINNÆUS: Syst. Nat., ed. 10, 1, 149, 1758 (Sweden).

We found this sandpiper common in the Weï valley and throughout southern Shen-si in April and May. It is a characteristic bird of the lower reaches of the mountain rivers, At that season it is usually found singly or in pairs.

Specimen No. 6043. Collected April 17, 1904, along the gravelly banks of the Heï-shui-ho, near Chóu-chï-hién, Shen-si.

(?) **Rhyacophilus glareola** (LINNÆUS). *Wood Sandpiper.*

Tringa glareola LINNÆUS: Syst. Nat., ed. 10, 1, 149, 1758 (Sweden).

A few birds, closely corresponding to the description of this species were observed in the mountain valleys west of Pau-ting-fu, in January. They were always found singly along the gravelly banks of the river.

Ibidorhynchus struthersi VIGORS. *Ibis-bill.*

Ibidorhynchus struthersi VIGORS: Proc. Comm. Sci. Zool. Soc. Lond., 1, p. 174, March 2, 1832 (Himalayas).

This species appears to be confined to the mountain valleys. In January the birds were frequently observed along the Sha-ho, in western Chï-li. The weather at that time was not severe (10° to 40° F.), but much of the time the river was bordered with thin ice. We found them again on the other side of the divide, in the Wu-t'ai district of Shan-si. Scattered birds were seen also in the Ts'in-lings, in the months of April and May.

The ibis-bill usually goes in small companies or singly, and frequents the stony banks of the swift mountain rivers. It is a very noisy bird, and when disturbed makes its canyon home ring with its shrill cries.

Specimen No. 6022. Collected January 19, 1904, at Fóu-p'ing-hién, Chï-li.

(?) **Gallinago** sp. *Snipe.*

Snipe, which were believed to be of this genus, were rather common near Fóu-p'ing-hién, Chï-li, and also in the Wu't'ai district during the winter. They are usually found about springs or in sheltered sunny places in the valley, where ice has not formed and there is some growth of grass. In general appearance, and also in the character of its alarm note, this species reminded me strongly of *Gallinago delicata*, of the United States. Also observed in the mountainous portion of Shan-tung, during October and November.

COLUMBIDÆ.

Columba rupestris PALLAS. *Gray Rock-pigeon.*

Columba rupestris PALLAS: Zoogr. Ross.-As., 1811, 1, 560.

In northern China, wherever there are mountains, we found this one of the most characteristic birds. It was also common in the Khilok valley in eastern Siberia, in September. During the autumn and winter the birds congregate in flocks, roosting among the ledges of the high cliffs. This species is particularly abundant in Shan-tung and Chï-li. In Shan-si we found it associated with the next species in ever-decreasing numbers as we progressed southward.

Columba domestica GMELIN. *Blue Rock-pigeon.*

Columba domestica GMELIN: Syst. Nat., I, part 2, 769, 1788.

We saw this bird only in Shan-si and in the valley of the Weï-ho. Although it is not absent from the mountains, it is much more abundant among the villages and cultivated fields of the valleys and lowlands.

Turtur decaocta (FRIVALDSKY). *Indian Ring-dove.*

Columba decaocta FRIVALDSKY: Balkányi Természet. Utazásról, 1838, 30, pl. 8 (Balkan region).

In the northeastern provinces this is the commonest species of the genus. It remains during the winter in small numbers, at least as far north as Peking. Like the rock-pigeon, the ring-dove was not observed in the Ts'in-ling mountains; but in the extreme southern part of the province we saw certain individuals which appeared to belong to this species. It is a bird of the villages, making its nest in the poplars or in the small cedars which the Chinese usually plant near their graveyards.

Specimen No. 6006. Collected October 30, 1903, at Ch'ang-hia, Shan-tung.

Turtur chinensis (SCOPOLI). *Chinese Turtle-dove.*

Columba chinensis SCOPOLI: Del. Fl. et Faun. Insubr., II, 94, 1786 (China).

Either this bird has a more pronounced migratory habit than the last, or else its habitat is normally farther to the west, for with the exception of one individual seen during January in west Chï-li, we saw none of them until we reached the province of Shan-si. It happened, however, that we arrived there at the opening of spring and the facts may be explained by this coincidence. Even in Shan-si we saw few birds of this species, and in the Weï valley it was scarcely common. Although we observed none in the Ts'in-ling mountains, we found them again in the valleys of the Han and its larger tributaries.

The wine-red breast and spotted neck of this dove make it one of the most beautiful of those found in China. It may be readily distinguished from the other two species here mentioned, by the broad white margin on the tail which is rendered conspicuous when the bird is in flight.

Turtur orientalis (LATHAM). *Rufous Turtle-dove.*

Columba orientalis LATHAM: Index Ornith., II, 606, 1790 (China).

This form very largely replaces the other two species south of the valley of the Weï-ho. It is a common species in the Ts'in-ling mountains and thence southward at least as far as the Yang-tzï river.

Specimen No. 6045. Collected April 18, 1904, in the foothills of the Ts'in-ling mountains, near Heï-shui-k'ou.

PHASIANIDÆ.

Coturnix (?) sp. *Quail.*

A very small quail, evidently of this genus, was seen on several occasions in the mountains near Fóu-p'ing, Chï-li. The birds were always encountered singly in sheltered nooks, high up in the heads of the valleys. The natives call this bird "Ngan-ch'un," which means "quail."

Caccabis chukar (GRAY). *Chukar Partridge.*

Perdix chukar GRAY: Ill. Ind. Zool., I, 1830, pl. 54 (India).

We found this partridge common in the mountains of Shan-si and Chï-li, during the winter, and also met with it occasionally in central Shan-tung. It appears to be common wherever there is sufficient shelter, but in the eastern provinces the inhabitants destroy the grass on the mountain slopes each year, and so render the place unfavorable for the habitation of such birds. Its favorite haunts are brushy mountainsides, in the sparsely

inhabited portions of Chī-li and Shan-si. During the winter it is usually seen in small coveys. When alarmed they cackle volubly, but if not too closely pursued, they will usually sneak through the grass rather than fly.

Chrysolophus pictus (LINNÆUS). *Golden Pheasant.*

Phasianus pictus LINNÆUS: Syst. Nat., ed. 10, I, 1758, 158 (China).

The golden pheasant is a fairly common bird in the basin of the Han river, in Shen-si. Although we seldom saw it alive, we found pheasants of this species for sale in villages in the Ts'in-lings and along the Nan-kiang.

(?) **Phasianus decollatus** SWINHOE.

Phasianus decollatus SWINHOE: Proc. Zool. Soc. Lond., 1870, 135 (Szechuen).

The commonest pheasant of southern Shen-si probably belongs to this species. We saw single individuals here and on our journey through the Ts'in-lings and the valley of the Han river, and the loud and characteristic call of the male bird was one of the common sounds of the region. At Ta-ho-pa, on the 7th of May, I saw several newly hatched chicks of this species which had been captured in the neighborhood.

FALCONIDÆ.

Haliætus albicilla (LINNÆUS). *Gray Sea-eagle.*

Falco albicilla LINNÆUS: Syst. Nat., ed. 10, I, 1758, 89 (Sweden).

Observed occasionally along the Sha-ho, in the mountains of western Chī-li, in January.

Buteo sp.

Large hawks of this genus (probably *B. hemilasius*) were common in Shan-si, through February and March. They frequent the large poplars about the villages on the plains, and in these situations they evidently make their nests undisturbed. The scream of this bird is much like that of the red-tailed hawk (*B. borealis*) of the United States.

Erythropus amurensis (RADDE). *Eastern Red-legged Falcon.*

Falco vespertinus (L.) var. amurensis RADDE: Reisen im Süden von Ost-Sibirien, II, 1863, 102, plate 1, 2 (Amurlande).

Although we saw this only in eastern China, during the autumn it was one of the most abundant birds. Several of these little falcons could be seen, at almost any time, soaring leisurely over the harvest fields and frequently stopping to hover over some point which seemed to attract their attention. They were almost as numerous among the marshes which border the Yellow river.

Specimen No. 6001. Collected October 12, near Tö-chóu, Shan-tung.

Milvus melanotis TEMMINCK & SCHLEGEL. *Black-eared Kite.*

Milvus melanotis TEMMINCK & SCHLEGEL: Fauna Japonica 1845, 14, plate 5 (Japan).

Next to the magpie and the house sparrow the black-eared kite is probably the most wide-spread and familiar bird in China. From the plains of Manchuria southwest to Shen-si and the Yang-tzī valley, its presence is rarely lacking. The favorite haunts of these birds are the villages and cities; Peking and other capitals support hundreds of them, and as they show little fear of men, it is evident that they are not often molested. In winter their huge nests are conspicuous in the trees of such cities, and a view of the city wall seems hardly complete without one or two kites perched upon the battlements. But this species is by no means confined to the populous plains; its hoarse screams are quite as familiar sounds among the rugged mountains of Shan-si and Shen-si.

Like most other hawks the black-eared kite begins its nesting early. Several pairs were observed building late in March, in southern Shan-si.

Circus cyaneus (LINNÆUS). *Blue Harrier.*
Falco cyaneus LINNÆUS: Syst. Nat., ed. 12, 1766, I, 126 (near London).

This harrier was observed only in the Weï valley, during the months of March and April. Its habits are too familiar to require special mention here.

Circus melanoleucus (PENNANT). *Pied Harrier.*
Falco melanoleucus PENNANT: Indian Zool., 1769, II (India or Ceylon).

Seen on the marshes of the south branch of the Sungari river, in central Manchuria, during September.

CUCULIDÆ.

Cuculus canorus telephonus (HEINE). *Kamchatkan Cuckoo.*
Cuculus telephonus HEINE: Journ. für Orn., 1863, 352 (Japan).

A cuckoo which agrees closely with the description of this species was common in southern Shen-si, in May.

ALCEDINIDÆ.

Ceryle rudis varia (STRICKLAND). *Pied Kingfisher.*
Ceryle varia STRICKLAND: Ann. and Mag. Nat. Hist., VI, 1841, 418.

We saw the pied kingfisher frequently along the mountain streams of southern Shen-si, as far north as the Ts'in-ling divide.

Halcyon smyrnensis (LINNÆUS). *White-breasted Kingfisher.*
Alcedo smyrnensis LINNÆUS: Syst. Nat., ed. 10, I, 1758, 116 ("Africa and Asia").

This was the least common of the three kingfishers seen in China. A single individual, probably this species, was observed on the P'ing-li river, in southern Shen-si, in May.

Alcedo ispida bengalensis (GMELIN). *Little Indian Kingfisher.*
Alcedo bengalensis GMELIN: Syst. Nat., I, 1758, 450 (Bengala).

This gorgeous little kingfisher first came to our notice in southern Manchuria, during September, but owing to the advent of cold weather, it did not appear again until we reached southern Shen-si in the following May. Unlike the larger kingfishers, this species seems to prefer a perch very low over the water, and its rapid and direct flight, as well as its brilliant colors, remind one somewhat of the humming-birds. It is fairly common along the large streams of southern Shen-si.

UPUPIDÆ.

Upupa epops LINNÆUS. *Hoopoe.*
Upupa epops LINNÆUS: Syst. Nat., ed. 10, I, 1758, 117 (Sweden).

The hoopoe was common in Shan-si and Shen-si from the middle of March to June. We did not meet with it in the Yang-tzï valley, but it probably occurs there. It is also rather common in Shan-tung in the late autumn, but only a single bird was seen in the mountains of West Chï-li, in January. It is a bird of the villages, frequenting orchards and groves, especially in hill districts or even in the mountains, but never very far from human habitation.

MICROPODIDÆ.

(?) Micropus pacificus (LATHAM). *Large White-rumped Swift.*
Hirundo pacifica LATHAM: Ind. Ornith. Suppl., 1801, LXIII ("Nova-Hollandia").

A large swift, which is doubtless of this species, was seen at Liang-ho, in the southern part of the Ts'in-ling mountains. Several birds were skimming incessantly about the rugged hills which border the valley at this point. They move with incredible swiftness. It seemed to delight them to swoop toward some object until they seemed certain to be

dashed to pieces, and then suddenly swerve aside, avoiding the object by a few inches. Probably no bird is more unerring in its flight or shows more confidence in its ability. This black swift may be distinguished by its large size and the white patches which are conspicuous on the throat and rump.

Tachornis infumata (SCLATER). *Eastern Palm-swift.*

Cypselus infumata SCLATER: Proc. Zool. Soc. London, 1865, 602 (Banjermassing, Borneo).

A little brown swift, believed to be of this species, was common among the northern foothills of the Ts'in-ling mountains, in April. In small companies they skim over the rugged hillsides or haunt the canyons of this district.

PICIDÆ.

Dryobates cabanisi (MALHERBE). *Mandarin Woodpecker.*

Picus cabanisi MALHERBE: Journ. für Orn., 1854, 172 (China).

This handsome woodpecker is common throughout most of north China. We found it in Shan-tung in the late autumn, in the mountains of western Chï-li in January, and in the Weï valley in April. Its favorite haunts are the orchards and poplar groves which usually accompany the small villages.

Gecinus canus zimmermanni (REICHENOW). *Chinese Green Woodpecker.*

Picus c. zimmermanni REICHENOW: Ornith. Monatsb. XI, 1903, 86 (Kiautschou).

This is a familiar bird throughout the year in almost every village in the provinces of Shan-tung, Chï-li and Shan-si, being more common than the last species. In its actions it reminded me strongly of the flicker (*Colaptes auratus*) of the United States.

This variety differs but little from *Gecinus c. perpallidus* Stejneger, of the Ussuri province, Siberia. Our only specimen comes from Shan-si, but as the type-locality is eastern Shan-tung the range of this race doubtless includes all of the three northeastern provinces of the empire of China. Dr. Richmond's remarks regarding this bird are here quoted in full:

"The single female collected (6034, T'ai-yüan-fu, Shan-si, March 6) by Mr Blackwelder, agrees more closely with the description of Reichenow's *zimmermanni* than with the type of *perpallidus* Stejneger (U. S. National Museum, from Sidimi, Ussuri, November 25). It differs from the latter in having the back darker, with a deeper shade of olive greenish on the wings; the sides of the body and of the neck are also perceptibly darker, while the black malar stripe is barely indicated. Wing, 150.5; tail, 100; tarsus, 26.5; culmen, 44.5 mm."

Gecinus guerini (MALHERBE). *Guerin's Green Woodpecker.*

Chloropicus guerini MALHERBE: Revue et Mag. de Zool. I, 1849, 539 ("China").

This species replaces *G. canus*, in the Ts'in-ling mountains and to the southward. Whether the green woodpeckers of the Weï-ho valley belong to this, or to the preceding species, we are unable to say.

Specimen No. 6065. Collected May 5 in the little mountain village near Ts'ai-kia-kuan, Shen-si.

ALAUDIDÆ.

Alaudula minor cheleensis (SWINHOE). *Chï-li Sand-lark.*

Alaudula cheleensis SWINHOE: Proc. Zool. Soc. London, 1871, 390 (Talien Bay, Liau-tung province, China).

A common species on the plains of Shan-si in the winter. During the earliest weeks of spring it soars and sings after the manner of larks in general. Its dull color corresponds so closely to that of the plowed fields at this season, that it is almost impossible to distinguish the bird when it is upon the ground.

Specimen No. 6029. Collected Feb. 26, 1904, on the plain south of Hin-chóu, Shan-si.

Calandrella brachydactyla dukhunensis (SYKES). *Rufous Short-toed Lark.*

Alaudula dukhunensis SYKES: Proc. Comm. Sci. Zool. Soc. Lond., II, 1832, 93 ("Stony plains of Dukhun.")

This retiring little lark was seen only in the plain of the Weï-ho and in the northern part of the Ts'in-lings, but there it is common wherever there are cultivated fields. When alarmed the bird squats upon the ground or skulks through the short grass rather than take wing.

Specimen No. 6041. Collected April 13, 1904, in a wheat-field near Chóu-chï-hién, Shen-si.

Specimen No. 6052. Collected April 23, 1904, in a cultivated field on a mountain spur (elevation 3,000 feet, 900 meters), near Liu-yüé-ho, Shen-si.

Galerita cristata leautungensis (SWINHOE). *Long-billed Crested Lark.*

Alauda leautungensis SWINHOE: Ibis, 1861, 256 (Talien Bay, Liau-tung province, China).

Few birds are more characteristic of the plains of northern China than this species. It winters in southern Manchuria and the northern tier of the eighteen provinces, taking the place occupied in the United States by our familiar shore-larks (*Otocoris*). In April after leaving the valley of the Weï-ho on our journey southward, we saw no more of this species. Although common upon the plains, it evinces a preference for hilly or even mountainous country, and in Shan-tung one meets small companies of them even on the summits of the highest peaks. A crested lark is occasionally seen in cages in the villages, but as a singer it is inferior to the succeeding species.

Specimen No. 6002. Collected October 20, on the mountain west of Ch'au-mi-tién, Shan-tung.

Melanocorypha mongolica (PALLAS). *Mongolian Sand-lark.*

Alauda mongolica PALLAS: Reise Russ. Reichs, III, 1776, 697 (between the rivers Onon and Argun in Dauria).

We saw this bird only in captivity, and in that condition it is one of the commonest birds in northern China, being the variety most popular with the village shop-keepers. It becomes very tame and apparently contented in its cage life, and at times shows a decidedly playful disposition. The Chinese call the bird "Pai-ling."

MOTACILLIDÆ.

Numerous species of this family, and particularly of the genus *Motacilla*, are found in various parts of China and Manchuria at different seasons of the year. Their variations are so complex that it is unsafe to attempt to identify birds of this genus in the field. We shall, therefore, mention only the varieties of which specimens were collected.

Motacilla ocularis SWINHOE. *Swinhoe's Wagtail.*

Motacilla ocularis SWINHOE: Ibis, 1860, 55 (Amoy, China).

This species was fairly common in the late autumn, along the mountain streams in central Shan-tung, but was not seen elsewhere in the empire.

Specimen No. 6010. Collected November 3, 1904, at Ch'ang-hia, Shan-tung.

Motacilla alba baikalensis (SWINHOE). *Baikal Wagtail.*

Motacilla baikalensis SWINHOE: Proc. Zool. Soc. London, 1871, 363 (Baikal region).

The Baikal wagtail is abundant during the spring in northwestern China. It made its appearance in southern Shan-si about the middle of March, and continued to be common all along the road until we reached the Yang-tzï in June. This species nests in southern Shen-si, as well as in Siberia. During March and April the birds congregate in loose flocks along the gravelly river-beds of the Weï valley, but later they distribute themselves in pairs along the mountain streams. In these places, early in May, the young of the year were observed following their parents.

Specimen No. 6037. Collected April 8, 1904, at Chóu-chï-hién, Shen-si.

CALANDRELLA BRACHYDACTYLA DUKHUNENSIS (SYKES). SHORT-TOED LARK.

Motacilla boarula melanope (PALLAS). *Gray Wagtail.*

Motacilla melanope PALLAS: Reise Russ. Reichs, III, 1776, 696 (Dauria).

A bird of the mountain brooks. It was seen only in the Ts'in-ling mountains and the basin of the Han river. It nests in this region during April, and by the second week in May the young birds are out of the nest.

Specimen No. 6050. Collected April 23, 1904, in the canyon of the Heï-shui-ho (elevation 2,500 feet, 750 meters), Ts'in-ling mountains.

Anthus spinoletta blakistoni (SWINHOE). *Blakiston's Pipit.*

Anthus blakistoni SWINHOE: Proc. Zool. Soc. London, 1863, 90 (Yang-tzĭ river, 150 miles, 240 kilometers, inland).

We found this pipit in the meadows among the higher mountains west of Fóu-p'ing-hién, Chï-li, in January. A similar bird, presumably of this variety, was not uncommon along the streams in Shan-tung in November. The species was again met with in the Weï-ho valley in April. In their actions the birds closely resemble *Anthus pennsylvanicus* of the United States.

Specimen No. 6021. Collected January 19, at Fóu-p'ing-hién, Chï-li.

Specimen No. 6339. Collected April 13, at Chóu-chï-hién, Shen-si.

The remarks of Dr. Richmond, concerning these specimens, are as follows:

"There are two specimens in the collection, one from Chĭ-li (January 19), and the other from Shen-si (April 13). Both are marked as females on the labels, but there is a considerable difference in size, particularly in the length of the wing. Both of these birds differ from descriptions of *A. s. blakistoni*, in that the penultimate tail feather has no white spot at the tip, but merely a narrow white edging on the outer web. The April bird is in spring plumage, and is much too pale on the under parts and superciliary stripe for *A. japonicus*. Sharpe gives the dimensions of the wing in Indian examples of *blakistoni* as 86.5 to 79 mm., while Swinhoe's type measured 94 mm. The specimens collected by Mr. Blackwelder furnish the following:

"Chĭ-li: female, Jan. 19, wing, 90; tail, 69; tarsus, 23.

"Shen-si: female, April 13, wing, 83; tail, 64; tarsus, 23; culmen, 17."

Anthus hodgsoni RICHMOND. *Indian Tree-pipit.*

Anthus maculatus HODGSON, in Gray's Zool. Miscl., 1844, p. 83; Jerdon, Birds of India, III, 1864, 873 (nec *Motacilla maculata* GMELIN).

This appears to be uncommon in the regions which we visited and we saw it on but one occasion. A small flock was encountered near the summit of a mountain (elevation 7,000 feet, 2,100 meters) in the northern Ts'in-ling mountains, on May 1st. Here there was a grassy slope, interspersed with scattered pines; and unlike most pipits, these birds took refuge in the pine trees when alarmed, instead of keeping to the ground.

Specimen No. 6063. Collected May 2, 1904, near Siau-wang-kién, Shen-si.

TIMALIIDÆ.

Following the system proposed by Gadow, we include here the families usually distinguished as the Garrulacidæ and Paradoxornithidæ.

Myiophoneus cæruleus (SCOPOLI). *Chinese Whistling Thrush.*

Gracula cæruleus SCOPOLI: Del. Flor. et Faun. Insubr. II, 1786, 88 ("China").

This species was observed occasionally along the turbulent mountain brooks of the southern Ts'in-lings, early in May.

Pomatorhinus gravivox DAVID. *Shen-si Scimitar-babbler.*

Pomatorhinus gravivox DAVID: Ann. Sci. Nat. (Zool.), ser. 5, XVIII; 1873, art. 5, p. 2 (Province Shen-si, China).

We found this bird not uncommon in the brushy canyons on the north slope of the Ts'in-ling range, late in April. Evidently this is its nesting season, and any intrusion into

during the nesting period, they set up a scolding twitter not unlike that of some American wrens. By the 20th of April, these birds evidently had eggs or young in the nests, and about four weeks later I noticed troops of fully grown young accompanying their parents.

Specimen No. 6062. Collected May 2, 1904, near Siau-wang-kién, at an elevation of 5,000 feet, 1,500 meters.

Yuhina diademata VERREAUX. *White-naped Yuhina.*

Yuhina diademata VERREAUX: Nouvelles Archives du Museum, v, fasc. 4, 1869, 35 ("Setchuan Moupin").

A few pairs of this handsome species were seen in the valley of the Han river at Shï-ts'üan-hién, May 11. In their actions they resemble species of *Zonotrichia* (United States).

PYCNONOTIDÆ.

Pycnonotus xanthorrhous ANDERSON. *Anderson's Yellow-vented Bulbul.*

Pycnonotus xanthorrhous ANDERSON: Proc. Asiatic Soc. Bengal, 1869, 265 (Yünnan, China: "Manwyne, Yunan, alt., circa 1,700 pedes angl.").

This is one of the characteristic and familiar birds of the south Shen-si region in May. Its disposition is energetic and pugnacious, reminding one strongly of the kingbirds of the United States. This similarity is even increased by the slight occipital crest and by the bird's habit of dashing after prey, capturing it on the wing and returning again to the favorite perch. The cry of this bulbul is harsh and is repeated at frequent intervals with variations. About the first week in May it was apparent, from the actions of the birds that they had either eggs or nestlings at the time.

Spizixos semitorques SWINHOE. *Half-collared Bulbul.*

Spizixos semitorques SWINHOE: Ibis, 1861, 266 (Pehling plateau, near Foochow, China).

Although somewhat less common than the last species, this is a familiar bird in the same localities. It frequents the shrubby tangles in the valleys, and there places its nest.

PRUNELLIDÆ.

Laiscopus erythropygius (SWINHOE). *Red-rumped Accentor.*

Accentor erythropygius SWINHOE: Proc. Zool. Soc. London, 1870, 124, plate 9 ("Kemeih, Prefecture of Suenhwafoo, north China").

This accentor prefers the ruggedest cliffs and canyons among the high mountains. We found it near the summit of the T'ai-shan, in Shan-tung, early in November, and in the limestone canyons of the Wu-t'ai region, Shan-si, in February. At this season of the year the birds go in companies of three to six, which may perhaps be families of the previous summer. Even in winter the bird indulges in a low sweet warble which is very pleasing.

Specimen No. 6013. Collected November 11, 1903, near the summit of the T'ai-shan, Shan-tung.

Specimen No. 6026. Collected February 15, 1904, in the canyon of the T'ai-shan-ho, Yau-t'óu district, Shan-si.

Specimen No. 6032. Collected February 28, 1904, in a canyon on the southern edge of the Hin-chóu basin, Shan-si.

Dr. Richmond's remarks regarding these specimens, are as follows:

"There are three adults in the collection, from the provinces of Shan-si and Shan-tung. These differ from a specimen collected on Askold Island, near Vladivostok, in having shorter wings and bills; and the gray of the head, neck, and breast is clearer and less brownish. The differences are not great, but still appreciable, and it is not improbable that two forms may eventually be recognized. Swinhoe's type was

collected September 26, at Kemeih, in the 'Prefecture of Seuenhwafoo,' about 75 miles northwest of Peking. The measurements of this bird, as given by Swinhoe, (converted into millimeters), with those of the specimens mentioned above, are here added:

"Kemeih, Sept. 26, adult, wing, 107; tail, 76; tarsus, 22; culmen, 14.
"Askold Is., Oct. 7, wing, 105; tail, 66.5: tarsus, 25; culmen, 18.5.
"T'ai-an-fu, Shan-tung, Nov. 10, wing, 96; tail, 64; tarsus, 23.5; culmen, 17.5.
"Wu-t'ai-hién, Shan-si, Feb. 15, wing, 98; tail, 62; tarsus, 23; culmen, 17.
"Hin-chóu, Shan-si, Feb. 28, wing, 100; tail, 65.5; tarsus, 22.5; culmen, 16.5."

Prunella montanella (PALLAS). *Daurian Accentor.*

Motacilla montanella PALLAS: Reise Russ. Reichs, III, 1776, 695 ("Dauuria").

This is one of the characteristic birds of the rocky ravines of the Chī-li-Shan-si mountains, in winter. Singly or in pairs, they are met in almost every gulch, flitting in and out among the boulders and rugged ledges along the brooks.

Specimen No. 6025. Collected February 9, 1904, in the canyon of the Shī-t'ou-ho, Wu-t'ai region, Shan-si.

TURDIDÆ.

Here are included the former families Saxicolidæ, Sylviidæ and Turdidæ (restricted).

Pratincola maura (PALLAS). *Indian Bush-chat.*

Motacilla maura PALLAS: Reise Russ. Reichs, II, 1773, 708 (West Siberia, between Tobol and Irtysh rivers).

This elegant little bush-chat was seen only in the canyon of Heī-shui-ho, Shen-si, during the latter part of April. Several of them were observed flitting among the low bushes in the neighborhood.

Petrophila solitaria (LINNÆUS). *Western Blue Rock-thrush.*

Turdus solitarius LINNÆUS: Syst. Nat., ed. 10, I, 1758, 170 ("Oriente").

Of this beautiful azure stone-chat I saw only a single individual. The bird was flitting along the rocky banks of the P'u-ho, in the southern Ts'in-lings, early in May. Large boulders were its favorite perches, but its nervous activity did not allow it to remain long at any one spot.

Chaimarrornis leucocephalus (VIGORS). *White-capped Redstart.*

Phœnicura leucocephalus VIGORS: Proc. Comm. Sci. Zool. Soc. London, I, March 2, 1831, 35 ("Himalayas").

A beautiful and striking bird which is rather common along the swift rivers in the canyons of the Ts'in-ling mountains, during April and May. It is rarely seen away from the rocky ledges and bouldery rapids. Evidently it makes its nest in almost inaccessible crevices in the cliffs overhanging the water.

Specimen No. 6064. Collected May 3, 1904, on the headwaters of the P'u-ho (elevation 6,500 feet, 2,000 meters), near the Ts'in-ling divide.

Rhyacornis fuliginosa (VIGORS): *Plumbeous Redstart.*

Phœnicura fuliginosa VIGORS: Proc. Comm. Sci. Zool. Soc. London, I, March 2, 1831, 35 ("Himalayas").

In the spring and summer there is no more familiar bird along the mountain streams than this somber little redstart. It keeps to the bouldery beds of the swift streams and nests in crevices among the rocks close to the water. The eggs are laid late in April and before the close of May the young are able to fly. This bird has a peculiar habit of wagging the tail up and down with a rhythmic motion, resembling the manipulation of a fine silk fan.

Specimen Nos. 6058 and 6060. Collected April 29, 1904, at Siau-wang-kién.

Regarding these specimens, we quote Dr. Richmond:

"One pair of adults from Shen-si province. These are identical in color with Kashmir and Indian birds:
"Shen-si, April 28, wing, 81; tail, 55.5; tarsus, 23.5; culmen, 14.5.
"Shen-si, April 29, wing, 76; tail, 49.5; tarsus, 22; culmen, 14.5."

Microcichla scouleri (VIGORS). *Little Forktail.*

Enicurus scouleri VIGORS: Proc. Comm. Sci. Zool. Soc. London, I, 1832, 174 ("Himalayas").

We saw this bird only in the canyons of the mountains between the Han and the Yang-tzï rivers, and rarely even there. Its habits are essentially like those of the last species described. The plumage is black and white, the white parts being arranged in such a manner that they form a conspicuous white cross when the bird is in flight; by this means it may be recognized at once.

Phœnicurus auroreus (PALLAS). *Daurian Redstart.*

Motacilla aurorea PALLAS: Reise Russ. Reichs, III, 1776, 695 (Baikal region, "Circa Selengam et collaterales fluvios").

From March until June we found this a common bird in the Weï-ho valley and the mountainous region to the south of it. It was also seen on the T'ai-shan, in Shan-tung, in November. Usually it frequents low trees and shrubs, but it alights frequently upon the ground, returning to the trees at intervals to devour what it has found. Its nests are placed in shrubs and the young birds appear to be hatched about the middle of May.

Specimen No. 6036. Collected March 30, 1904, in willows along the road near Lin-tung-hién, Shen-si.

Specimen No. 6046. Collected April 24, 1904, among the bushes of a deep mountain canyon, in the northern Ts'in-lings.

(?) **Phœnicurus grandis** (GOULD). *Gould's Redstart.*

Ruticilla grandis GOULD: Proc. Zool. Soc. London, part 17, 1850, 112 ("Afghanistan and Thibet").

Birds, agreeing with description of this species, were occasionally seen among the mountains of Shan-si, in February. They were usually in small companies, feeding on the seeds of dry herbage, near the summits of the mountain peaks (4,000 to 7,000 feet, 1,200 to 2,100 meters). The only note heard at this season is a metallic chirp, not unlike that of the redpoll.

Ianthea cyanura (PALLAS). *Red-flanked Bluetail.*

Motacilla cyanurus PALLAS: Reise Russ. Reichs, II, 1773, 709 (Siberia "Circa Ieniseam)."

Late in the autumn we secured one of these birds in a grove of willows, at Ch'ang-hia, Shan-tung. The species was not seen during the winter, but during the latter part of March it appeared again among the willows and fruit-trees in the Weï valley. It is a quiet little warbler, with something of the flycatcher's dash and activity about its movements.

Specimen No. 6008. Collected November 3, 1903, at Ch'ang-hia, Shan-tung.

Phylloscopus proregulus (PALLAS). *Pallas's Willow Warbler.*

Motacilla proregulus PALLAS: Zoogr. Rosso.-Asiat. I, 1811, 499 (Eastern Siberia—"Ad Ingodam fluvium Dauriæ).

We found this a common species in the Ts'in-ling mountains and the valley of the Han, in April and May. Its favorite resorts are the budding shrubs, especially those which are in flower at that season. The willow warbler has a thin wiry little song which is audible only at a comparatively short distance.

CINCLIDÆ.

(?) **Cinclus sordidus** GOULD. *Somber Dipper*

Cinclus sordidus GOULD: Proc. Zool. Soc. London, 1859, 494 ("Cashmere").

In the higher mountains west of Pau-ting-fu, wherever turbulent brooks and waterfalls offer it a favorable habitat, a sooty black ouzel, agreeing with descriptions of this

species, is common. It remains here through the winter, and dips without hesitation into partially frozen streams on the coldest days. The alarm note of this species is a loud metallic "penk." One also hears, even at this season, its vivacious wren-like song.

Cinclus pallasii TEMMINCK. *Pallas's dipper.*

Cinclus pallasii TEMMINCK: Man. d'Ornith, ed. 2, 1820, I, 1776 (Crimea).

This species replaces the last in the Ts'in-ling mountains and the higher regions of southern Shen-si. The habits of the two birds are similar.

TROGLODYTIDÆ.

Olbiorchilus fumigatus idius RICHMOND (new subsp.). *Chi-li Winter-wren.*

This little wren is found among the mountains of southeastern China during the winter, but seems to be rather rare at that season. A single specimen was seen in a rocky ravine on the T'ai-shan, Shan-tung, in November. We encountered a few others among the rugged mountains about Fóu-p'ing-hién, in Chī-li, and the Wu-t'ai-shan region, Shan-si, in January. It seems to prefer gulches where large boulders and ledges of rock afford abundant chinks and crevices. At this season of the year the bird is comparatively silent and was always seen alone.

Specimen No. 6014. Collected November 11, 1903, at an elevation of 2,000 feet, 600 meters, on T'ai-shan, Shan-tung.

Specimen No. 6017. Collected January 16, 1904, at Wang-kuai-chŏn, Chī-li.

Dr. Richmond's description of this new variety and his remarks upon it are as follows:

"Type—Adult male, No. 192449, U. S. National Museum; Wang-kuai-chŏn, Chī-li, China, Jan. 16 1904; Eliot Blackwelder (original number, 6017). Top of head, nape and mantle brown (between wood-brown and sepia of Ridgway's Nomenclature of Colors), becoming tinged with burnt umber on the back and rump; upper tail-coverts mummy brown, the feathers (as are also those of the mantle, back, and rump) somewhat narrowly barred with blackish. Wings dusky brown, barred with wood-brown and buffy-white on the outer webs of outer primaries; inner primaries, secondaries, and tertiaries Mars brown externally, barred or mottled with blackish; lesser wing-coverts like the mantle, and indistinctly barred with blackish; middle coverts similar, but some of the feathers tipped with white; greater coverts Mars brown, barred with blackish, some of the feathers with narrow buffy tips; primary coverts like the latter, but without paler tips; tail feathers mummy brown, darker on the inner webs, irregularly barred with black. Lores and chin wood brown, becoming drab on the middle of the throat; sides of throat, sides of neck and chest broccoli brown, tinged with wood brown, the chest rather plentifully dotted with small dusky spots; sides of head and ear coverts streaked with wood brown, the streaks becoming less distinct on the sides of the neck; superciliary stripe pale wood brown, passing to the posterior border of the ear-coverts; breast, sides of body and abdomen pale drab, inclining to cinnamon on the sides, barred and mottled with dusky, more heavily on the abdomen and flanks, where some of the feathers have whitish tips; under tail-coverts mummy brown barred with blackish and tipped with white; under wing-coverts and edges of wing pale drab-gray barred with blackish. Wing, 52.5; tail, 33.5; tarsus, 18; culmen, 15 mm.

"This form is much lighter than *fumigatus*, *dauricus*, or *nipalensis*, almost as pale, in fact, as some specimens of *neglectus* in fresh plumage; but it differs from the latter in having the pale streaks extending on the sides of the neck and in the more conspicuous whitish tips on the middle wing-coverts. In these characters it agrees with Sharpe's description of *talifuensis* (Bull. Brit. Orn. Club, XIII, 1902, p. 11) but that bird is said to be nearest to *nipalensis*, which is very dark above and below. *O. tibetana*, of Walton, is a much larger bird."

Another example of this new form was collected at T'ai-an-fu, Shan-tung province, November 11, 1903. It is a female and differs from the type mainly in being slightly darker or more rusty on the upper surface, and in having the pale streaks on the sides of the neck more pronounced. These differences are probably due to its fresher plumage.

TROGLODYTES FUMIGATUS IDIUS RICHMOND. CHI-LI WINTER WREN.

PERICROCOTUS BREVIROSTRIS (VIGORS). SHORT-BILLED MINIVET.

HIRUNDINIDÆ.

Hirundo rustica gutturalis (SCOPOLI). *Eastern Swallow.*

Hirundo gutturalis SCOPOLI: Del. Floræ et Faunæ Insubr. II, 1786, 96 (Panay, Philippines).

By the middle of March these swallows appeared on the plateau of southern Shan-si, and during the rest of our journey to the Yang-tzï we met them occasionally. They seemed to prefer the well-inhabited plains and broad valleys. We saw none among the high ranges of the Ts'in-ling-shan nor in the canyon region of southern Shen-si and eastern Ssï-ch'uan, but they were abundant in the vicinity of cities, such as Hing-an-fu and P'ing-li. Swallows of similar appearance were common on the plain of the Huang-ho, in October, and also along the Manchurian railroad, in September. At Dauria, Mongolia, a number had built their nests under the eaves of the railroad station; the meager description of this bird recorded at the time applies better to *H. rustica tytleri* Jerdon of India than to the present variety, but the data are insufficient in this case for a reliable determination.

Specimen No. 6042. Collected April 13, 1904, on the muddy flats bordering the Weï-ho, near Chóu-chï-hién, Shen-si.

Hirundo daurica nipalensis (HODGSON). *Hodgson's Striated Swallow.*

Hirundo nipalensis HODGSON: Jour. Asiatic Soc. Bengal, V, 1836, 780 (Nepal).

We saw this bird in May between the Ts'in-ling divide and the Yang-tzï. In that region it is rather more common than *H. r. gutturalis* and does not share the latter's predilection for towns and cities. It nests among rocky ledges bordering the rivers and thus finds a congenial home in the very canyons which the preceding species avoids.

(?) Riparia riparia LINNÆUS. *Sand Martin.*

Hirundo riparia LINNÆUS: Syst. Nat., ed. 10, I, 1758, 192 (London).

Banks of clay or sand, affording nesting sites for this species, are not numerous in the mountainous region of the west; but wherever these conditions are favorable the bank swallow appears. We saw it only at Shï-ts'üan-hién, on the Han river and locally on the Ta-ning-ho.

CAMPEPHAGIDÆ.

Volvocivora melanoptera (RÜPPELL). *Pale-gray Cuckoo-shrike.*

Cebleptyris melanoptera RÜPPELL: Mus. Senckenb. III, 1, 1839, 25, plate 2, 1 ("Neu Holland," probably Burmah or S. China).

This is one of the birds seen occasionally in the luxuriant growth of shrubbery, in the valleys of southern Shen-si.

Pericrocotus brevirostris (VIGORS). *Short-billed Minivet.*

Muscipeta brevirostris VIGORS: Proc. Comm. Sci. Zool. Soc., London, I, April 6, 1831, 43 ("Himalayas").

This brilliant red and black species was observed only in the shady woods, remnants of which have escaped the general destruction of forests in certain parts of the Ts'in-ling mountains.

Specimen No. 6057. Collected April 27, 1904, near Ïr-ling-p'u, in a wooded mountain gulch (elevation 6,000 feet, 1,800 meters). Measurements of this adult male are: Wing, 89; tail, 100; tarsus, 16; culmen, 16 mm.

DICRURIDÆ.

Dicrurus sp. (*cf. D. cathœcus*).

In southern Shen-si we frequently saw a bird which resembles this species in all particulars except in having a yellow beak (that of Swinhoe's bird was black). Its peculiar cries may be heard at all times during the day, but especially toward nightfall. It utters a loud strenuous whistle of two notes, of which the latter is strongly accented and drawn out. In each cry the bird seems to be making an effort to project the sound as far as possible. Swinhoe describes the notes of this bird as being "loud and discordant," but the notes of the Shen-si species are clear and penetrating rather than discordant.

In order to facilitate identification in the future, the field description of this bird is appended: "About the size of the crow-blackbird (United States). Plumage entirely black. Legs greenish. Beak light yellow. Eyes red."

Buchanga leucogenis WALDEN. *White-cheeked Drongo.*

Buchanga leucogenis WALDEN: Ann. Mag. Nat. Hist. series v, March, 1870, 219 (Nagasaki, Japan).

This was first seen in the southern Ts'in-lings, early in May, and occasionally thereafter as far as the Yang-tzĭ river. At this season of the year the birds are always seen in pairs. They nest in large trees and the young are hatched late in May. This bird prefers as a perch the uppermost branches of the tallest trees. There it sits, nearly motionless, as it watches for its prey, and then dashes out after it as do the flycatchers.

Specimen No. 6074. Collected May 30, 1904, at Ta-ning-hién, Ssĭ-ch'uan.

LANIIDÆ.

Several species of the genus *Lanius* were observed in different parts of the empire, but none were satisfactorily identified.

(?) **Lanius tigrinus** DRAPIEZ. *Thick-billed Shrike.*

Lanius tigrinus DRAPIEZ: Dict. Class. d'Hist. Nat. XIII, 1828, 523 (Java).

A bird, apparently of this species, was seen in a cage in Peking. The Chinese call it "Shan-hsüeh."

SITTIDÆ.

Sitta sinensis VERREAUX. *Chinese Nuthatch.*

Sitta sinensis VERREAUX: Nouv. Archives du Mus. Bull. VI, 1870, 34 (Kiu-kiang, Chinese Tibet).

Nuthatches appear to be rare throughout that part of China which we visited. On one occasion only, I observed what was apparently this form, climbing about a large oil-nut tree in the valley of the Han river, Shen-si.

PARIDÆ.

Parus cinereus minor (TEMMINCK & SCHLEGEL). *Japanese Gray Chickadee.*

Parus minor TEMMINCK & SCHLEGEL: Fauna Japonica, Aves, 1850, 70, plate 33 (Japan).

We found this chickadee throughout the whole of our journey, from the coast of Shantung to eastern Ssĭ-ch'uan. Among the cedars of T'ai-shan it was especially common in the autumn, and we found it nesting in the Ts'in-ling mountains, in April and early May. The call of the Japanese chickadee differs but slightly from that of our American varieties, and the habits of the various members of the genus seem to be similar.

Specimen No. 6019. Collected January 17, 1904, at Wang-kuai-chŏn, Chĭ-li.

Specimen No. 6051. Collected April 25, 1904, in the canyon of the Heĭ-shui-ho, Ts'in-ling mountains.

BUCHANGA LEUCOGENIS WALDEN. WHITE-FACED DRONGO.

PARDALIPARUS VENUSTULUS (SWINHOE). SHORT-BILLED TIT.

(?) Lophophanes dichrous (HODGSON). *Brown-crested Tit.*
Parus dichrous HODGSON: Gray's Zool. Miscellany, 1844, 83 (Nepal).

A brownish gray-crested titmouse, which seems to coincide with Gould's figure of this species, was observed near the Ts'in-ling divide at Wön-kung-miau, early in May. We found them in the thick growth of deciduous shrubs, trees and scattered pines above 7,000 feet, 2,100 meters, elevation. At this altitude there was considerable snow. The birds appeared in small loose companies, flitting through the shrubbery. They were rather tame and evinced a strong curiosity regarding the intruders into their domain. Like most members of the family they scold and chatter when their suspicions are aroused.

Pardaliparus venustulus (SWINHOE). *Short-billed Tit.*
Parus venustulus SWINHOE: Proc. Zool. Soc. London, 1870, 133 (Yang-tzĭ river, between Kweifoo, Szechuan, and Ichang, in Hoopih).

Observed on several occasions among the flowering shrubs and fruit-trees, in the valleys of the Ts'in-lings and the southern part of the Han basin, in April and May. A quiet little bird of deliberate movements, its actions reminding one somewhat of the American vireos.

Specimen No. 6048. Collected April 23, 1904, in the canyon of the Heĭ-shui-ho, Shen-si.

(?) Aegithalos concinnus (GOULD). *Chinese brown-headed Tit.*
Psaltria concinnus GOULD: Birds of Asia, II, 1855, plate 65 (China).

In the basin of the Han, in Shen-si, a bright-colored little titmouse, which is evidently of this species, or a closely allied form not yet described, finds a suitable home in the tangles of vine and shrubbery. By the 10th of May, the young birds are out of the nest, and the parents show great solicitude when an intruder appears, keeping up a scolding chatter until he withdraws. At this time they are very fearless and will approach within a few feet of one.

ORIOLIDÆ.

Oriolus indicus JERDON. *Black-naped Oriole.*
Oriolus indicus JERDON: Illustr. Indian Orn., 1847, plate 15 (India).

A familiar species on account of its bright plumage and its loud call notes, in Shen-si south of the Ts'in-ling divide.

CORVIDÆ.

Corvus torquatus LESSON. *White-necked Crow.*
Corvus torquatus LESSON: Traité d'Orn., 1831, 328 ("Australia" = China).

A common species throughout northern China. During the winter we found it rarely among the high mountains of Chĭ-li and Shan-si, but abundant again on the fertile plains of the We-ho. The birds are usually seen singly or in pairs and do not share the gregarious habit of some other members of the genus.

Corvus macrorhynchos japonensis (BONAPARTE). *Japanese Crow.*
Corvus japonensis BONAPARTE: Consp. Avium, I, 1850, 386 (Japan).

The common black crow, or "lau-kung" as it is called by the natives, is widely distributed in northern China as far as Manchuria and southeastern Siberia. Flocks of considerable size are commonly seen on the cultivated plains of Shan-tung and Shen-si, in the autumn and spring.

Corvus frugilegus pastinator (GOULD). *Chinese Rook.*
Corvus pastinator GOULD: Proc. Zool. Soc. London, 1845, I (Chusan, China).

It is difficult to distinguish this variety in the field from the related species just mentioned. Both are said to be common throughout the northern provinces.

Pica pica sericea (GOULD). *Chinese Magpie.*

Pica sericea GOULD: Proc. Zool. Soc. London, 1845, 2 (Amoy, China).

In China no bird is as nearly omnipresent as the magpie. From Manchuria and even Transbaikalia to Ssï-ch'uan, every village, however small, whether on the plain or in the narrow mountain valleys, has its representatives and these remain the year round. The Chinese call it "Si-ch'iau," or "hopping bird," because of its habit of hopping about farmyards and inns, almost as if it were a domestic fowl. In March, we found them busily engaged in building their bulky nests in the large poplar trees among the villages of Shan-si and before the middle of May the young birds had left the nest.

Colœus dauricus (PALLAS). *Daurian Jackdaw.*

Corvus dauricus PALLAS: Reise Russ. Reichs, III, 1776, 694 (Baikal region).

We saw this jackdaw first at Aga, Transbaikalia, in September. From there onward to Shan-tung and southwest as far as the Weï-ho valley, it was a common bird during the winter. The species is rather more characteristic of hilly and mountainous regions than of the plains, but it is also a common associate of the magpies and crows in the populous lowlands. When a large flock is feeding on level ground, the birds in the rear seem continually dissatisfied with their situation and fly forward to the front ranks, and thus the entire flock gradually progresses. A similar habit is characteristic of the cow-bird (*Molothrus*) of the United States.

Colœus neglectus SCHLEGEL. *Japanese Jackdaw.*

Corvus neglectus SCHLEGEL: Bijdr. Dierk. Amsterdam, afl., 8, 1859, Art. Corvus, 16 (Japan).

The black jackdaw may be seen occasionally in the flocks of *C. dauricus*, in southern Shan-si and the Weï valley. It replaced the latter species entirely in the valley of the Han river during May, but it was not very common even there.

Cyanopica cyana swinhoei HARTERT. *Swinhoe's Black-capped Jay.*

Cyanopica cyanus swinhoei HARTERT: Vögel paläarkt. Fauna, Heft 1, 1903, 24 (Kiukiang, China).

Like the magpie this is a bird of the villages. It is rarely seen in mountainous regions, but is commonest on the rich plains of Shen-si and southeastern China. Its stealthy flight and especially its soft whining notes, reminded me of the Canada jay (*Perisoreus canadensis*).

Urocissa erythrorhyncha (BODDAERT). *Chinese Blue-pie.*

Corvus erythrorhynchus BODDAERT: Table Pl. enl., 1783, 38 (ex Pl. Enl. 622, China).

This magnificent jay is probably a migratory species. In January only a single individual was seen in the mountains of west Chï-li, but it was fairly common in the Ts'in-lings and to the southward, during May. There it prefers wooded ravines at rather low altitudes. Its notes are varied and mimetic, and yet they are distinctly corvine in the harsh quality of the tones.

Pyrrhocorax pyrrhocorax (LINNÆUS). *Alpine Chough.*

Upupa pyrrhocorax LINNÆUS: Syst. Nat., ed. 10, 1, 1758, 118 ("Angliæ Ægypti maritimis").

This is a mountain bird *par excellence*. Whether in Shan-tung, Chï-li, or in the Ts'in-lings it is never seen far from the high cliffs which are its refuge and nesting place. We found it especially abundant among the limestone crags of west Shan-tung. At that season (late autumn) they combine in small flocks, but in the spring only single pairs are seen. The flight of this bird is easier and more buoyant than that of any corvide I have yet seen. They spend hours on the wing, swooping and gyrating about the cliffs, apparently for the sheer joy of flying. It is also a very noisy bird, with its petulant but rather musical croak exultingly uttered as it flies.

Nucifraga caryocatactes macrorhynchos (BREHM). *Large-billed Nutcracker.*

Nucifraga macrorhynchos BREHM: Lehrb. Europ. Vögel, I, 1823 103 (Germany: a straggler).

Observed only in the wildest part of the Ts'in-lings (above 4,000 feet, 1,200 meters, elevation) near the divide. Here considerable forests still remain and these harbor birds which have been driven away from the other parts of the mountains.

STURNIDÆ.

Spodiopsar cineraceus (TEMMINCK).

Sturnus cineraceus TEMMINCK: Pl. Col., II, 1832, 556 (Japan).

This is a common associate of the jays and magpies, in the village groves and orchards from Shan-tung to Shan-si and the Weï valley. In the Ts'in-lings it is much less common and south of them it was not observed at all. In October large flocks were feeding upon berries which grow on certain trees on the plain of the Huang-ho.

Æthiopsar cristatellus (LINNÆUS).

Gracula cristatella LINNÆUS: Syst. Nat., ed. 10, I, 1758, 109 (China).

A familiar species in the southern Ts'in-lings and the valley of the Han. It lives about the farm-houses and is often seen hopping over the half-flooded rice-fields, like a magpie. The only call heard at this season is a squealing sound.

ZOSTEROPIDÆ.

Zosterops simplex SWINHOE. *Swinhoe's Silver-eye.*

Zosterops simplex SWINHOE: Ibis 1861, 331 (Southern China).

This little greenlet is rather common in the flowering trees and bamboo thickets, along the tributaries of the Han river in Shen-si during May.

Zosterops erythropleura SWINHOE. *Chinese Silver-eye.*

Zosterops erythropleura SWINHOE: Proc. Zool. Soc. London, 1863, 204 (Shanghai, China).

Offered for sale in the bird market at Tien-tsin. The native name for it is "Pai-yeh," which means "white cheek."

FRINGILLIDÆ.

Fringilla montifringilla LINNÆUS. *Brambling.*

Fringilla montifringilla LINNÆUS: Syst. Nat., ed. 10, I, 1758, 179 (Sweden).

Apparently this species does not winter in the northern provinces. We found it common in Shan-tung, in October and November, but saw none thereafter until they appeared in the Weï-ho valley in March. In Shan-tung they frequented the cedar groves about graveyards and upon the slopes of the T'ai-shan. Here numbers of them are caught with bird-lime and are then sold as cage-birds. To the bird-catchers it is known as "Hu-pieh" (Tiger bird).

(?) Spinus spinus (LINNÆUS). *Siskin.*

Fringilla spinus LINNÆUS: Syst. Nat., ed. 10, I, 1758, 181 (Sweden).

Siskins, which appear to be of this species, were found on the T'ai-shan and neighboring mountains, in company with the last-named species.

Chloris sinica (LINNÆUS). *Chinese Greenfinch.*

Fringilla sinica LINNÆUS: Syst. Nat., ed. 12, I, 1766, 321 (China).

The greenfinch, or "Huang-ch'iau" (yellow bird), we saw frequently in the spring, on the road from central Shan-si to southern Shen-si. None were observed, however, in the more rugged portions of the Ts'in-ling mountains. The flight of this bird is like that of the American goldfinch, but the chirp is sharp and metallic.

Specimen No. 6033. Collected March 5, 1904, in the hills north of T'ai-yüan, Shan-si.

Acanthis linaria holboelli (BREHM). *Holboell's Redpoll.*
Linaria holboelli BREHM: Handb. Vög. Deutschl., 1831, 280 (Germany).

This wide-spread linnet was found in the Shan-tung mountains in November and in western Chĭ-li later in the winter. The Chinese make some use of it as a cage-bird and it goes by the name of "Hung-ku-t'ou" (red bone bird).

Specimen No. 6007. Collected November 3, 1903, at Ch'ang-hia, Shan-tung.

Carpodacus roseus (PALLAS). *Rosefinch.*
Fringilla rosea PALLAS: Reise Russ. Reichs, III, 1776, 699 (Baikal region).

Winters in central Shan-tung and Shan-si. In the latter province it was occasionally observed in small flocks, feeding upon the seeds of dry weeds in the heads of mountain gulches, in February.

Specimen No. 6005. Collected October 30, 1903, at Ch'ang-hia, Shan-tung.

Specimen No. 6031. Collected February 29, 1904, in a mountain ravine (elevation 6,500 feet, 2,000 meters), south of Hin-chóu, Shan-si.

(?) Loxia curvirostra albiventris (SWINHOE). *White-bellied Crossbill.*
Loxia albiventris SWINHOE: Proc. Zool. Soc. Lond., 1870, 437 (near Peking).

Crossbills were not uncommon in November, in the cedar groves of Shan-tung. The current name among the Chinese is "Chou-p'u-tsui."

Leucosticte brunneonucha (BRANDT). *Brown-naped Leucosticte.*
Fringilla brunneonucha BRANDT: Bull. Sci. Acad. St. Petersb., X, 1842, 252 (Kamschatka).

In February we saw a large flock of these birds on the grassy summit of the mountain south of the Hin-chóu basin, Shan-si, at an elevation of 6,500 feet, 2,000 meters. Their flight was swift and gyratory and they were always restless.

(?) Calcarius lapponicus (LINNÆUS). *Lapland Longspur.*
Fringilla lapponica LINNÆUS: Syst. Nat., ed. 10, I, 1758, 180 (Lapland).

In Shan-tung and Chĭ-li the writer heard the characteristic notes of this bird frequently as flocks of them passed overhead; but as the birds were never seen clearly the identification is not conclusive.

Passer montanus (LINNÆUS). *Tree Sparrow.*
Fringilla montana LINNÆUS: Syst. Nat., ed. 10, I, 1758, 183 (Europe).

From the time that we entered Manchuria at the north, until we left China at Shanghai, scarcely a day passed in which we did not see this sparrow, which is known among the Chinese as "Cha-ch'iau." Like their congeners in the United States these chattering, bickering sparrows are to be found in every city, town, and village at all seasons of the year.

Passer rutilans (TEMMINCK). *Japanese Sparrow.*
Fringilla rutilans TEMMINCK: Pl. Col. III (Livr. 99), 1835, plate 588 (Japan).

Among the isolated rice-farms of Shen-si, south of the Ts'in-ling divide, this is a fairly common bird. It is by no means such a house-loving species as the last, but prefers the groves and trees adjoining the farmyards.

(?) Pycnorhamphus sp.

In the wooded valleys of the southern Ts'in-lings and Han river, we occasionally saw a dark grosbeak which closely resembles *P. carneipes* Hodgson. It differs from the latter, however, in having a coral-red beak. It is possible that this is an undescribed species of the genus, and for the benefit of future explorers of this region the original field description of it is appended:

"A stout bird about the size of the pine grosbeak (United States). The male is mostly dull brownish-black, shading into dark cinnabar green on the lower breast and abdomen. A patch of white on the primaries. Beak very stout and coral red. The female differs only in having the body-color dull dark greenish, changing to a bluish-green tinge on the primaries, below the white patch."

(?) **Eophona personata magnirostris** HARTERT. *Amur Grosbeak.*

Eophona personata magnirostris HARTERT: Bull. Brit. Ornith. Club, v, 1896, XXXVIII (Amur-land).

On the T'ai-shan, Shan-tung, we saw several of these birds in cedar groves. The Chinese tame the grosbeaks and teach them a variety of simple tricks. One of these is to fly after and retrieve a light ball of pith tossed into the air. Among the bird fanciers it is known as "La-tsui" (hot-bill).

Emberiza rustica PALLAS. *Rustic Bunting.*

Emberiza rustica PALLAS: Reise Russ. Reichs, III, 1776, 698 (Dauria).

Common in the hedges and orchards of the Shan-tung hills, in October and early in November.

Specimen No. 6004. Collected October 30, in a cedar grove near Ch'ang-hia.

Specimen No. 6009. Collected November 3, 1903, among willows in a mountain gully near same place.

Emberiza castaneiceps MOORE. *Chestnut-headed Bunting.*

Emberiza castaneiceps MOORE: Proc. Zool. Soc. London for 1855, February 5, 1856, 215 ("Kin-tang, in China").

This is the commonest member of the genus in the mountains of Shan-tung and western Chī-li, during the winter. On account of its preference for mountain ravines and hillsides, the natives call the bird "Shan-cha-ch'iau" (mountain sparrow), to distinguish it from the house sparrow.

Specimen No. 6003. Collected October 9, 1903, at Ch'ang-hia, Shan-tung.

Specimen No. 6012. Collected November 15, 1903, in long grass on the summit of T'ai-shan (elevation 5,000 feet, 1,500 meters).

Emberiza leucocephala S. G. GMELIN. *Pine Bunting.*

Emberiza leucocephala GMELIN: Novi Comm. Petrop., XV, 1771, 480, plate 23, 3 ("Astrachan").

This bunting is probably common during the winter in Shan-si and western Chī-li, but it is easily confused with *E. castaneiceps*.

Specimen No. 6018. Collected January 14, 1904, in a grove of cedar trees, near Ning-shan, Chï-li.

Emberiza yunnanensis SHARPE. *Yünnan Bunting.*

Emberiza yunnanensis SHARPE: Bull. Brit. Ornith. Club, XIII, October 31, 1902, 12 ("Gyi-dzin-shan, east of Talifu, western Yunnan").

This takes the place of *E. castaneiceps*, in Shan-si and Shen-si, from the Wu-t'ai region to the southern boundary of the latter province. It is especially common about the brushy gulches in the Ts'in-ling mountains.

Specimen No. 6027. Collected February 17, 1904, in a canyon in the Yau-t'óu district, eastern Shan-si.

Emberiza elegans TEMMINCK. *Elegant Bunting.*

Emberiza elegans TEMMINCK: Pl. Col. III (livr. 98), 1835, plate 583, 1 (Japan).

This handsome species is characteristic of the high Ts'in-lings and the mountains of the Han basin, in April and May. It makes its nest in the underbrush along the water courses.

Specimen No. 6049. Collected April 23, 1904, at Liu-yüé-ho, in the valley of the Heï-shui-ho, Shen-si.

Emberiza sulphurata TEMMINCK & SCHLEGEL. *Sulphur-bellied Bunting.*

Emberiza sulphurata TEMMINCK & SCHLEGEL: Fauna Japonica, Aves, 1850, 100, pl. 60 (Japan).

This species was observed only in the higher parts of the Ts'in-ling mountains, early in May, in company with the last species.

Specimen No. 6059. Collected April 29, 1904, at Siau-wang-kién.

Emberiza passerina PALLAS. *Pallas's Bunting.*

Emberiza passerina PALLAS: Reise Russ. Reichs, I, 1771, 456 (Siberia (?), "Obs. ad Iaicum autumno").

This Siberian species evidently winters in northern China, but we observed it on only one occasion. Several were flushed from the short grass bordering a frozen river in the western mountains of Chï-li, in January.

Specimen No. 6020. Collected January 18, 1904, near Wang-k'uai-chön, Chï-li.

Emberiza pusilla PALLAS. *Dwarf Bunting.*

Emberiza pusilla PALLAS: Reise Russ. Reichs, III, 1176, 697 ("Dauuria").

This little bunting was fairly common in Shen-si in the spring. It was first seen on the plain of the Weï-ho, in the shrubbery about the villages, and later we met with it more frequently in the Ts'in-ling mountains, as far south as the Han river. The birds were found nesting in dense undergrowth, at Tsai-kia-kuan, May 5.

Specimen No. 6038. Collected April 8, 1904, along the roadside west of Si-an-fu, Shen-si.

CLASS MAMMALIA.

Mammals are by no means common in most parts of northern China. In the more densely populated portions of the empire the reasons for this are obvious: the forests have been destroyed, the human race appropriates almost all of the vegetation capable of supporting mammals, and the larger quadrupeds are of course exterminated by hunters. In the mountains a variety of mammals still remain, but they are much rarer than they would be if the natural forest cover had not been so extensively destroyed.

It was not possible to devote much time during our journey to the collection of mammals and, on account of the fact that as a class they are less often seen than other animals, we made few observations on them in the field. We are indebted to Mr. Gerrit S. Miller, Jr., for the taxonomic portion of the brief notes which follow.

ANNOTATED LIST OF MAMMALS.

Moschus sp. *Muskdeer.*

A species of this genus is found in the Ts'in-ling mountains, but it appears to be very uncommon. The animals are hunted assiduously by the natives and are valued not only for their musk but also for the small tusks in the upper jaw. These teeth are used by the Chinese in their medical practices and are said to act as charms or talismans to drive off various pains and ills.

(?) **Sus scrofa** (var.). *Wild boar.*

Wild swine seem to be common in the Ts'in-ling mountains. According to the natives they are very destructive to growing crops, especially potatoes. The animals descend at night upon the village fields in small droves, and the inhabitants are obliged to station watchers every night before the crops are harvested. Even this practice is not always successful.

Citellus sp.

These little burrowing rodents are fairly common on the plains of southern Shan-si and the Weï valley in Shen-si. In their general habits they resemble the spermophiles of central United States.

Specimen No. 6035, shot in a wheat-field west of Tung-kuan, Shen-si, March 28, 1904.

(?) Lepus sinensis GRAY. *Chinese hare.*

A tawny or buff-colored hare is fairly common upon the plains of eastern China and in the less mountainous portions of the four northern provinces. It was not observed south of the Weï-ho valley, in Shen-si.

(?) Vulpes vulpes (var.). *Fox.*

The foxes were seen not infrequently in Shan-tung, Chï-li, Shan-si, and Shen-si. In the more accessible portions of the mountains most of the underbrush has been destroyed by the inhabitants and consequently these animals are met with only in the more remote valleys. The foxes which were seen in the eastern provinces, in winter, were distinctly grayish in color, but individuals in the Ts'in-ling mountains, in May, were buff or tawny.

In addition to the species named above, we saw several others regarding whose identity we have little evidence. These included mice, squirrel-like rodents, and a deer which resembles the roebuck. In the gorges of the Ta-ning-ho monkeys were not uncommon, but it would be unsafe to hazard a guess as to what species is here represented.

SECTION VI

SYLLABARY OF CHINESE SOUNDS

BY

DR. FRIEDRICH HIRTH

CHAPTER XVIII.

SYLLABARY FOR THE TRANSCRIPTION OF CHINESE SOUNDS IN THE DIALECT OF PEKING MODIFIED FOR LITERARY PURPOSES.

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INTRODUCTION.

The subjoined Syllabary is *mutatis mutandis* identical with the "Tabelle für die Laute des Chinesischen im Mandarin-Dialecte," submitted by me to the Far-Eastern Section of the XIII International Congress of Orientalists held at Hamburg in September, 1902.* From this table I have reproduced all the essential parts; but under column I (spelling in Williams' Dictionary) I have added one of the Chinese characters representing each group of sound; in column II (my own spelling) I have, in order to accommodate readers of English, changed the German initials *sch* and *tsch* into *sh* and *ch*, and in column III I have added the corresponding sounds in Wade's orthography of the Peking Dialect.

My own spelling, as represented in column II, is merely a compromise between Williams' and Wade's Syllabaries, to which I have added a few changes to be explained hereafter. The idea is not my own, but I have followed the precedent set by Dr. E. Bretschneider, who in his well-known works ("Botanicon Sinicum," "Mediæval Researches," etc.) made free use of Wade's system, while retaining the old Chinese standard initials *k*, *ts*, *h*, and *s* before *i* and *ü* as appearing in Williams' list of sounds against *ch* and *hs* in the Peking Dialect.

To be consistent, the maker of a map of China favoring the Peking orthography would have to spell *Chiang-hsi* for *Kiang-si*, *Nan-ching* for *Nan-king*, or *Fu-chien* for *Fu-kien*, and to please such writers we ought to look upon the greater part of the existing maps and charts containing Chinese names and a host of valuable books on China as obsolete. Peking spelling is, of course, a comfort to those who speak or study the dialect, but it does not lend itself to literary purposes. Sir Thomas Wade, who invented the system now applied to the Peking vernacular, wished it himself to be confined to that purpose and did not want it "even to profess

* Published in the Transactions of the Congress and reprinted in Prof. H. Cordier's Report, "Les études chinoises," 1899–1902, *T'oung pao*, 1903, pp. 38–45, and *Beiträge zur Kenntniss des Orients*, vol. 1, München, 1903.

to represent, or supplant, the standard or established pronunciation of the Mandarin language."*

The following examples representing syllables familiar to students of Chinese geography or history will illustrate the difference in the standard spelling which has been sanctioned by tradition and the Peking orthography:

Standard Mandarin.	*Peking Dialect (Wade).*
kiang, river	*chiang*
kin, gold	*chin*
Ts'in, name of a dynasty	*Ch'in*
king, capital	*ching*
k'iau, bridge	*ch'iao*
kia, family	*chia*
K'ién-lung, Emperor's name	*Ch'ien-lung*
Kia-k'ing, " "	*Chia-ch'ing*
K'ang-hi, " "	*K'ang-hsi*
si, West	*hsi*
hién, a district	*hsien*
pa-siên, the Eight Fairies	*pa-hsien*
hiau, filial	*hsiao*
siau, small	*hsiao*
Kiu-kiang (Kewkeang)	*Chiu-chiang*

In making use of the spelling shown in the subjoined Syllabary, Williams' "Syllabic Dictionary of the Chinese Language" may serve as a key. By looking up in it the Chinese characters to be transcribed the sound appearing in column I (Williams) may be ascertained, while columns II and III contain my own and Wade's equivalents. Readers need not trouble too much about the pronunciation of these syllables, which should be looked upon as mere symbols for certain sound groups to which the characters to be transcribed belong. The phonetic principles on which the several sounds are here described correspond in spirit to those adopted by the Royal Geographical Society of London† and the United States Board on Geographical names.‡ The "Instructions" here inserted have been made to correspond as much as possible to the English and American standards referred to.

* See Professor Schlegel's paper, "On the extended use of the Peking system of orthography for the Chinese language" (published in *T'oung pao*, vol. VI, p. 499 *seqq.*, Leiden, 1896), reproducing Mr. W. F. Mayers' remarks, who, being himself a prominent speaker of the Peking dialect, warns against its use for literary purposes.

† See "Rules for the Orthography of Geographical Names," published by the Council of the Royal Geographical Society on December 11, 1891.

‡ See "Second Report of the United States Board on Geographical Names," 1890–1899. Second edition, Washington, March, 1901.

PRONUNCIATION.

An approximation only of the true sound is aimed at in this system. The vowels are to be pronounced as in Italian and on the continent of Europe generally, and the consonants as in English; but note certain slight modifications as described hereunder.

Vowels and Diphthongs.

a has the sound of *a* in father. Examples: *ma*, horse; *sha*, sand; *wan*, a bay; *shan*, mountain; *nan*, south.

e *or* **é** has the sound of *e* in men. Examples: *hiėn*, a district; *miėn*, face, surface; *süé*, snow; *t'iė*, iron; *yé*, wild; *hüé*, cavern; *t'iėn*, field; *yen*, salt.

i has the sound of *i* in ravine, or of *ee* in beet. Examples: *si*, west; *tsi*, rocks under water; *k'i*, a rivulet; *ni*, mud; *i* (also read *yi*), city, hamlet.

NOTE: *i* is short as *i* in sin, or *i* in view, when followed by *n*, by another vowel or a diphthong. Examples: *kin*, gold; *ts'ing*, blue; *kia*, family; *kiang*, river; *tiėn*, palace; *k'iau*, bridge; *k'iai*, a model.

ï signifies that a vowel is to be intonated simultaneously with the adjoining sonant. See Note 2, below. Examples: *ch'ï*, a pool or lake; *shï*, stone, rock; *jï*, sun; *ssï*, a township; *tz'ï*, porcelain; *ïr*, two.

o has the sound of *o* in mote. Examples: *so*, a place; *ho*, a river; *fo*, Buddha; *po*, a marshy lake.

ö has the sound of *ö* in German, Hungarian, Swedish, Norwegian and Danish, or of *eu* in French jeu, or of *o* in English love. Examples: *mön*, gate, door; *shöng*, a province; *tö*, virtue.

NOTE: To describe this sound Wade makes use of the symbol *é* familiar to speakers of French in such words as honnête, where it has quite a different sound, though, from the one it stands for in Wade's orthography.

u has the sound of *oo* in boot. Examples: *ku*, lake; *ku*, valley; *fu*, a prefecture.

NOTE: u is short when preceding *n*, *a*, *o*, or a diphthong. Examples: *t'un*, village; *tung*, east; *kuang*, broad; *ch'uan*, river, water courses, *Ssï-ch'uan* province; *chuang*, a farm; *huang*, yellow; *kuan*, frontier pass, custom-house; *tuan*, short; *kuo*, kingdom; *k'uai*, quick.

ü is the umlaut of *u* and has the sound of *u* in French élu. Examples: *sü*, an islet; *kü*, embankment; *k'ü*, a drain; *hü*, market-place.

NOTE: *ü* is short when preceding *n*, *a*, or *é*. Examples: *sün*, a military station; *ts'üan*, fountain; *yüan*, source; *süé*, snow; *yüé*, moon.

ai has the sound of *i* in ice. Examples: *hai*, sea; *t'ai*, terrace, tower; *ch'ai*, stronghold, hill fortress; *ai*, cliff, ledge.

au has the sound of *ow* in how. Examples: *au*, a bay, cove; *kau*, high; *lau*, old; *miau*, temple.

eï has the sound of Italian *e* and *i* combined, somewhat like *ey* in English they. Examples: *heï*, black; *leï*, thunder; *meï*, coal; *peï*, north; *weï*, tail end.

óu is a diphthong in which the two elements are distinctly intonated, as in *t'óu*, head; which should have the sound of the first word in Hebrew tohu bohu without its *h*. Examples: *lóu*, a house with an upper story; *k'óu*, a mouth, embouchure, a port; *kóu*, a ditch; *hóu*, after, behind; *fóu*, a mound.

ui sounds like *ooi*, contracted into a diphthong, or like *ui* in German pfui. Examples: *shui*, water, river; *hui*, whirling waters; *tui*, a heap (as of rocks).

CONSONANTS.

NOTE: The initials, *k*, *p*, *tc*, *h*, *ts*, and *tz* should not be quite as hard as in English, though decidedly harder than *g*, *b*, *d*, *dj*, and *dz*. Thus the initial in *kan*, sweet, should hold about the middle between the initials in English gone and con. To indicate that *k*, *p*, *t*, *ch*, *ts*, and *tz* should be pronounced as hard as possible an asper is placed after them, which some printing offices replace by an apostrophe. Examples: *kan*, sweet; *k'an*, a pit; *ping*, soldier; *p'ing*, even, level; *to*, many; *lo-t'o*, a camel; *chau*, morning; *ch'au*, a dynasty; *tsiau*, half-tide rocks; *ts-'iau*, mountainous; *tzï*, purple; *tz'ï-hi*, gentle, or motherly, pleasure (principal name of the Empress Dowager).

ch — has the sound of *ch* in church, slightly softer when not marked and slightly harder when marked by an asper. Examples: *chóu*, island; *ch'öng*, walled city. When followed by *ï*, the vowel disappears in it. See below, Note 2.

k, p, t — as in English, king, poll, and tall, but slightly softer, and harder when marked by an asper. Examples: *kóu*, ditch, drain; *k'öng*, a pit; *pau*, a police ward; *p'u* shore, branch of a river; *tau*, island; *t'an*, a rapid.

ts — slightly softer than the two consonants would sound in English, and harder when provided with an asper. Examples: *tsö*, a pool; *ts'un*, village.

tz — similar to *ts*, the vowel disappearing in the sibilant. Examples: *tzï*, son; *tz'ï* a hall. See below, Note 2.

f — as in English. Examples: *föng*, summit, peak; *fóu*, a mound.

h — as in English, or as *x* in Spanish Xeres, both pronunciations being heard in North China. Examples: *hung*, red; *hüé*, a cavern; *hia*, a gorge.

j — as *j* in French jeu, and not as in English. Examples: *jön*, man; *jö*, hot. When followed by *ï* the vowel disappears in it. See below, Note 2.

l, m, n — As in English. Examples: *ling*, a mountain pass, range; *mi*, rice; *ni*, mud; *an*, a small temple; *kuan*, an inn.

r — dental, not gutteral, merely occurs in combination with the vowel *ï*, which disappears in it, so that it is difficult to say whether it is an initial or a final. See below, Note 2. Example: *ïr*, two.

sh — as in English show. Examples: *shang*, above. When followed by *ï*, the vowel disappears in it. See below, Note 2. Example; *shï*, ten.

ss — is a sharp sibilant, as in English mess, in which the vowel *ï* disappears. Example: *ssï*, a monastery. See below, Note 2.

w — as in English. Example: *wan*, gulf, bay.

y — a consonant, as in English yard. Examples: *yé*, wild land; *yen*, a precipice; *ying*, a military camp; *yüan*, an eddy.

ng — as a final, as *ng* in English song. Examples: *t'ing*, an inferior prefecture; *tsing*, a well; *yang*, ocean; *kang*, hill, ridge; *chung*, middle; *t'ang*, dyke, pool; *tung*, a cave. In certain words beginning with *a*, *ö*, or *o*, *ng* is optional as an initial, and should not appear in any transcription. Thus *an*, repose, is by some individuals pronounced *ngan*, for which reason we often read *Si-ngan-fu* instead of *Si-an-fu*.

NOTE 1. The accent in the vocalic combinations *óu*, *ié*, and *üé*, shows which of the two vowels is to be intonated foremost; it is otherwise not essential, and it must not be mistaken for a word-accent.

NOTE 2. I have comprised under one category what I call "the six difficult sounds," viz, *chï*, *shï*, *jï*, *ssï*, *tzï*, and *ïr*. By the symbol *ï*, which I have borrowed from Edkins, I wish to indicate the simultaneous intonation of a vowel, no matter which, with the adjoining sonant (*ch*, *sh*, *j*, *ss*, *tz*, or *r*). I have, at a meeting of the Far-Eastern Section of the XII International Congress of Orientalists, held at Rome October 10th, 1899, explained the reasons which have led me to use a uniform symbol for the vocalic elements of these six sounds, which appear as *chih*, *shih*, *jih*, *ssŭ*, *tzŭ* and *êrh* respectively, in Wade's, and as *chi* or *chih*, *shi*, *sh'* or *shih*, *jeh*, *sz*, *tsz*, and *'rh* in Williams' orthography. On referring to the old Chinese sound description quoted in K'ang-hi's Dictionary, it will be found that syllables are there explained by the so-called "cutting sound" method (*ts'iê-yin*). It consists of two characters, of which the first indicates the initial, the second, the final together with the vocalic content of the sound to be described. Since the six syllables referred to have, in the modern Mandarin dialects, no consonant as a final, the second character of their "cutting sound" represents merely their vocalic content pure and simple. And with regard to this vocalic content, uniformity may be shown to have been assumed by Chinese sound investigators in cases which in former systems are described by very different symbols. A few examples will illustrate this:

Wade spells 志 *chih*, K'ang-hi's analysis has 職 吏 **ch*(*ï-sh*)*ï* = *chï*

" " 寺 *ssŭ* " " " 祥 吏 *s*(*ïang-sh*)*ï* = *ssï*

" " 俑 *êrh*, " " " 仍 吏. *rj*(*öng-sh*)*ï* = *rï*, or *ïr*

It will be seen that in these three cases the Chinese express the final, or vocalic element in a uniform manner by 吏 *shï*,* whereas Wade expresses it in three different ways by *ih*, *ŭ* and *ê*. Furher

Wade spells 始 *shih*, K'ang-hi's analysis has 首 止 *sh*(*óu-ch*)*ï* = *shï*

" " 耳 *êrh* " " " 忍 止 *rj*(*ön-ch*)*ï* = *rï*, or *ïr*

" " 時 *shih* " " " 市 之 *sh*(*ï-ch*)*ï* = *shï*.

" " 而 *êrh* " " " 人 之 *rj*(*ön-ch*)*ï* = *rï*, or *ïr*.

" " 茲 *tzŭ* " " " 津 之 *ts*(*in-ch*)*ï* = *tsï*, or *tzï*.

" " 之 *chih* " " " 真 而 *ch*(*ön-r*)*ï* = *chï*.

" " 質 *chih* " " " 之 日 *ch*(*ï-jï*) = *chï*.

" " 日 *jih* " " " 人 質 *j*(*ön-ch*)*ï* = *jï*.

*The character for *li*, "an officer," read *shï* ad hoc (神 至 切 音 示, *K'ang-hi*).

The last two examples are cases in which the old sound had a consonant at the end; they are read *chat* and *yat* in Cantonese. But since no difference in sound is now heard between 徹 *chï* (Cantonese *chat*) and 之 *chï* (Cantonese *chi*), we are by analogy entitled to describe the sound for 日 (Cantonese *yat*) as *jï* in Mandarin.

The symbol *ï* thus denotes the amalgamation of a vowel with the adjoining sonant. I have also used it to describe the sound *eï* in *leï*, *meï*, etc., the *i* of which is but faintly heard by the side of *e*.

NOTE 3. I have followed the precedent set by Dr. Bretschneider in omitting the final *h* at the end of certain syllables, which in former systems was meant to indicate that a consonant (*t*, *k*, or *p*) appears in its stead in ancient Chinese and in the Southern dialects. Thus the word for "wood" used to be spelt *muh*, because its Cantonese, and probable ancient sound is *muk*. Bretschneider spells *mu*, because this is the sound actually heard in Northern China, the *h* at the end having none but historical value. When it is of importance to indicate the old final, I prefer to describe the word by "*mu* (Canton Dial. *muk*)."

SYLLABARY.

I. Williams.		II. Hirth.	III. Wade.
ai	矮	ai	ai
ang	昂	ang	ang
cha, chah	詐	cha	cha
	劄		
ch'a, ch'ah	茶	ch'a	ch'a
	察		
chai	寨	chai	chai
ch'ai	釵	ch'ai	ch'ai
chan	站	chan	chan
ch'an	產	ch'an	ch'an
chăn	眞	chön	chên
chen	占	chan	chan
ch'ăn	陳	ch'ön	ch'ên
ch'en	纏	ch'an	ch'an
chang	章	chang	chang
ch'ang	昌	ch'ang	ch'ang
chăng	爭	chöng	chêng
ch'ăng	橙	ch'öng	ch'êng
chao	照	chau	chao
ch'ao	鈔	ch'au	ch'ao
ché	遮	chö	chê
ch'é	車	ch'ö	ch'ê
cheh	折	chö	chê

I. Williams.		II. Hirth.	III. Wade.
ch'eh	撤	ch'ö	ch'ê
cheu	州	chóu	chou
ch'eu	抽	ch'óu	ch'ou
chi, chih	之	chï	chih
	質		
ch'i, ch'ih	齒	ch'ï	ch'ih
	尺		
ching	正	chöng	chêng
ch'ing	成	ch'öng	ch'êng
choh	棹	cho	cho
ch'oh	戳	ch'o	ch'o
chu, chuh	主	chu	chu
	竹		
ch'u, ch'uh	初	ch'u	ch'u
	出		
chui	追	chui	chui
ch'ui	吹	ch'ui	ch'ui
chun	准	chun	chun
ch'un	春	ch'un	ch'un
chung	中	chung	chung
ch'ung	虫	ch'ung	ch'ung
chwa	樝	chua	chua
chw'ai	揣	ch'uai	ch'uai

I. Williams.		II. Hirth.	III. Wade.
chwang	庄	chuang	chuang
chw'ang	床	ch'uang	ch'uang
chwen	專	chuan	chuan
chw'en	川	ch'uan	ch'uan
fah	法	fa	fa
fan	反	fan	fan
făn	分	fön	fên
fang	方	fang	fang
féi	非	feï	fei
feu	浮	fóu	fou
foh	縛	fo, fu	fu
fu	夫	fu	fu
fuh	佛	fu, fo	fu, fo
fung	風	föng	fêng
hai	海	hai	hai
han	汗	han	han
hăn	很	hön	hên
hang	杭	hang	hang
hăng	恒	höng	hêng
hao	好	hau	hao
heu	後	hóu	hou
hi	熙	hi	hsi
hih	迄		

I Williams.		II. Hirth.	III. Wade.
hia	下	hia	hsia
hiah	轄		
hiai	鞋	hié	hsieh
hiang	香	hiang	hsiang
hiao	孝	hiau	hsiao
hieh	協	hié	hsieh
hien	縣	hién	hsien
hin	忻	hin	hsin
hing	興	hing	hsing
hioh	學	hio	hsio, hsiao
hiu	休	hiu	hsiu
hiun	訓	hün	hsün
hiung	兄	hiung	hsiung
ho	河	ho	ho
hoh	合		
hu	胡	hu	hu
huh	鶻		
hwuh	忽		
hü	許	hü	hsü
hüé	靴	hüé	hsüeh
hüeh	血		
hüen	玄	hüan	hsüan

I. Williams.		II. Hirth.	III. Wade.
hung	紅	hung	hung
hwa, hwah	花滑	hua	hua
hwai	淮	huai	huai
hwan	患	huan	huan
hwang	黃	huang	hnang
hwo, hwoh	火或	huo	huo
hwui	回	hui	huei
hwun	昏	hun	hun
i, yih	夷益	i	i, yi
jan	染	jan	jan
jăn	人	jön	jên
jang	讓	jang	jang
jăng	仍	jŏng	jêng
jao	遶	jau	jao
jé	惹	jö	jo
jeh (a)	熱	jö	jê
jeh (b)	日	jï	jih
jeu	柔	jóu	jou
joh	若	jo	jo

I. Williams.		II. Hirth.	III. Wade.
jü, juh	如入	ju	ju
jui	蕊	jui	jui
jun	閏	jun	jun
jung	戎	jung	jung
jwa	稓	jua	jua
jwan	軟	juan	juan
kai	改	kai	kai
k'ai	開	k'ai	k'ai
kan	甘	kan	kan
k'an	看	k'an	k'an
kăn	根	kön	kên
k'ăn	懇	k'ön	k'ên
kang	岡	kang	kang
k'ang	康	k'ang	k'ang
kăng	更	köng	kêng
k'ăng	坑	k'öng	k'êng
kao	高	kau	kao
k'ao	考	k'au	k'ao
keu	狗	kóu	kou
k'eu	口	k'óu	k'ou
ki, kih	己吉	ki	chi

I. Williams.		II. Hirth.	III. Wade.
k'i, k'ih	其 乞	k'ī	ch'i
kia, kiah	加 甲	kia	chia
k'ia, k'iah	呿 恰	k'ia	ch'ia
kiai	街	kié	chieh
k'iai	楷	k'ié, k'iai	ch'iai
kiang	江	kiang	chiang
k'iang	羌	k'iang	ch'iang
kiao	教	kiau	chiao
k'iao	橋	k'iau	ch'iao
k'ié	茄	k'ié	ch'ieh
kieh	結	kié	chieh
k'ieh	怯	k'ié	ch'ieh
kien	見	kién	chien
k'ien	欠	k'ién	ch'ien
kin	金	kin	chin
k'in	琴	k'in	ch'in
king	京	king	ching
k'ing	慶	k'ing	ch'ing
kioh	角	kio	chio
k'ioh	確	k'io	ch'io

I. Williams.		II. Hirth.	III. Wade.
kiu	九	kiu	chiu
k'iu	丘	k'iu	ch'iu
kiün	君	kün	chün
k'iün	羣	k'ün	ch'ün
k'iüng	迥	k'iung	ch'iung
ko, koh	哥 各	ko	ko
k'o, k'oh	可 客	k'o	k'o
ku, kuh	古 骨	ku	ku
k'u, k'uh	苦 窟	k'u	k'u
kü, küh	居 局	kü	chü
k'ü, k'üh	去 曲	k'ü	ch'ü
küeh	掘	küé	chüeh
k'üeh	闕	k'üé	ch'üeh
küen	卷	küan	chüan
k'üen	犬	k'üan	ch'üan
kung	工	kung	kung
k'ung	孔	k'ung	k'ung

I. Williams.		II. Hirth.	III. Wade.
kwa, kwah	瓜 刮	kua	kua
kw'a	夸	k'ua	k'ua
kwai	怪	kuai	kuai
kw'ai	快	k'uai	k'uai
kwan	官	kuan	kuan
kw'an	寬	k'uan	k'uan
kwang	光	kuang	kuang
kw'ang	狂	k'uang	k'uang
kwéi	鬼	kui	kuei
kw'éi	葵	k'ui	k'uei
kwo, kwoh	過 國	kuo	kuo
kw'oh	闊	k'uo	k'uo
kwun	棍	kun	kun
kw'un	困	k'un	k'un
la, lah	喇 拉	la	la
lai	來	lai	lai
lan	闌	lan	lan
lang	郎	lang	lang
lăng	冷	löng	lêng
lao	老	lau	lao
leh	勒	lō	lê
léi	雷	leï	lei
leu	樓	lóu	lou
li, lih	里 力	li	li
liang	兩	liang	liang
liao	料	liau	liao
lieh	列	lié	lieh
lien	連	lién	lien
lin	林	lin	lin
ling	令	ling	ling
lioh	畧	lio	lio
liu	流	liu	liu
lo, loh	羅 落	lo	lo
lu, luh	路 陸	lu	lu
lü, lüh	呂 律	lü	lü
lüeh	劣	lié	lieh
lüen	孿	lüan	lüan
lun	輪	lun	lun

I. Williams.		II. Hirth.	III. Wade.
lung	龍	lung	lung
lwan	亂	luan	luan
ma, mah	馬 搖	ma	ma
mai	買	mai	mai
man	滿	man	man
măn	門	mön	mên
mang	忙	mang	mang
măng	盟	möng	mêng
mao	毛	mau	mao
mé	咩	mié	mieh
meh	陌	mo	mo
méi	梅	meï	mei
meu	謀	móu	mou
mi, mih	米 密	mi	mi
miao	苗	miau	miao
mieh	滅	mié	mieh
mien	面	mién	mien
min	民	min	min
ming	明	ming	ming
miu	繆	miu	miu
mo, moh	摩 墨	mo	mo
mu, muh	母 木	mu	mu
mung	蒙	möng	mêng
na, nah	那 納	na	na
nai	乃	nai	nai
nan	南	nan	nan
nang	囊	nang	nang
năng	能	nöng	nêng
nao	鬧	nau	nao
néi	內	neï	nei
neu	耨	nóu	nou
ngai	哀	ai	ai
ngan	安	an	an
ngăn	恩	ön	ên
ngao	澳	au	ao
ngeu	歐	óu	ou
ngo, ngoh	我 額	o, wo	o, wo
ni, nih	尼 匿	ni	ni

I. Williams.		II. Hirth.	III. Wade.
niang	娘	niang	niang
niao	鳥	niau	niao
nieh	揑	nié	nieh
nien	年	nién	nien
nin	您	nin	nin
ning	宇	ning	ning
nioh	虐	nio	nio
niu	牛	niu	niu
no, noh	挪諾	no	no
nu	奴	nu	nu
nü	女	nü	nü
nün	嫩	nun	nun
nung	農	nung	nung
nwan	煖	nuan	nuan
o	阿	a, o	a, o
pa, pah	巴八	pa	pa
p'a	怕	p'a	p'a
pai	拜	pai	pai
p'ai	牌	p'ai	p'ai
pan	半	pan	pan
p'an	盤	p'an	p'an

I. Williams.		II. Hirth.	III. Wade.
păn	本	pön	pên
p'ăn	盆	p'ön	p'ên
pang	榜	pang	pang
p'ang	傍	p'ang	p'ang
păng	迸	pöng	pêng
p'ăng	朋	p'öng	p'êng
pao	包	pau	pao
p'ao	砲	p'au	p'ao
péi	貝	peï	pei
p'éi	賠	p'eï	p'ei
p'eu	剖	p'óu	p'ou
pi, pih	比必	pi	pi
p'i, p'ih	皮闢	p'i	p'i
piao	標	piau	piao
p'iao	票	p'iao	p'iao
pieh	別	pié	pieh
p'ieh	撆	p'ié	p'ieh
pien	便	pién	pien
p'ien	片	p'ién	p'ien
pin	賓	pin	pin
p'in	品	p'in	p'in

I. Williams.		II. Hirth.	III. Wade.
ping	兵	ping	ping
p'ing	平	p'ing	p'ing
piu	彪	piau	piao
po / poh	波伯	po	po
p'o / p'oh	婆拍	p'o	p'o
pu / puh	布不	pu	pu
p'u / p'uh	普瞁	p'u	p'u
'rh	而	ïr	êrh
sah	撒	sa	sa
sai	賽	sai	sai
san	三	san	san
sang	桑	sang	sang
săng	僧	sŏng	sêng
sao	掃	sau	sao
seh	色	sö	sê
seu	叟	sóu	sou
sha / shah	沙殺	sha	sha
shai	曬	shai	shai
shan	山	shan	shan
shăn	神	shŏn	shên
shen	善	shan	shan
shang	上	shang	shang
shăng	生	shŏng	shêng
shao	少	shau	shao
shé / sheh	蛇舌	shŏ	shê
sheu	手	shóu	shou
shi, or sh' / shih	史石	shĭ	shih
shing	升	shŏng	shêng
shoh	芍	sho	sho
shu / shuh	書孰	shu	shu
shui	水	shui	shui
shun	順	shun	shun
shung	揰	ch'ung	ch'ung
shwa	刷	shua	shua
shwai	率	shuai	shuai
shwan	拴	shuan	shuan
shwang	霜	shuang	shuang
shwoh	說	shuo	shuo

I. Williams.		II. Hirth.	III. Wade.
si, sih	西息	si	hsi
siang	相	siang	hsiang
siao	小	siau	hsiao
sié, sieh	寫屑	sié	hsieh
sien	先	sién	hsien
sin	心	sin	hsin
sing	姓	sing	hsing
sioh	削	siau	hsiao
sui	秀	siu	hsiu
siün	旬	sün	hsün
so, soh	鎖索	so	so
su, suh	蘇肅	su	su
sü, süh	須恤	sü	hsü
süeh	雪	süé	hsüeh
süen	宣	süan	hsüan
sui	雖	sui	sui
sun	孫	sun	sun
sung	宋	sung	sung

I. Williams.		II. Hirth.	III. Wade.
swan	算	suan	suan
sz‘	四	ssï	ssŭ
ta, tah	大答	ta	ta
t‘a, t‘ah	他塔	t‘a	t‘a
tai	代	tai	tai
t‘ai	太	t‘ai	t‘ai
tan	丹	tan	tan
t‘an	炭	t‘an	t‘an
tang	當	tang	tang
t‘ang	湯	t‘ang	t‘ang
tăng	等	töng	têng
t‘ăng	籐	t‘öng	t‘êng
tao	道	tau	tao
t‘ao	桃	t‘au	t‘ao
teh	德	tö	tê
t‘eh	特	t‘ö	t‘ê
teu	豆	tuó	tou
t‘eu	頭	t‘óu	t‘ou
ti, tih	地狄	ti	ti

I. Williams.		II. Hirth.	III. Wade.
t'i, t'ih	提惕	t'i	t'i
tiao	弔	tiau	tiao
t'iao	條	t'iau	t'iao
tié, tieh	箑疊	tié	tieh
t'ieh	鐵	t'ié	t'ieh
tien	店	tién	tien
t'ien	天	t'ién	t'ien
ting	丁	ting	ting
t'ing	庭	t'ing	t'ing
tiu	丟	tiu	tiu
to, toh	多奪	to	to
t'o, t'oh	妥脫	t'o	t'o
tu, tuh	都毒	tu	tu
t'u, t'uh	土禿	t'u	t'u
tui	堆	tui	tui
t'ui	退	t'ui	t'ui
tun	遁	tun	tun

I. Williams.		II. Hirth.	III. Wade.
t'un	吞	t'un	t'un
tung	東	tung	tung
t'ung	同	t'ung	t'ung
twan	端	tuan	tuan
tw'an	團	t'uan	t'uan
tsa, tsah	咱雜	tsa	tsa
ts'ah	擦	ts'a	ts'a
tsai	在	tsai	tsai
ts'ai	才	ts'ai	ts'ai
tsan	贊	tsan	tsan
ts'an	鑽	ts'an	ts'an
tsăn	怎	tsön	tsên
tsang	葬	tsang	tsang
ts'ang	蒼	ts'ang	ts'ang
tsăng	增	tsöng	tsêng
ts'ăng	曾	ts'öng	ts'êng
tsao	造	tsau	tsao
ts'ao	草	ts'au	ts'ao
tseh	則	tsö	tsê
ts'eh	拆	ts'ö	ts'ê
tseu	走	tsóu	tsou
ts'eu	愁	ts'óu	tsou

I. Williams.		II. Hirth.	III. Wade.
tsi, tsih	祭集	tsi	chi
ts'i, ts'ih	齊七	ts'i	ch'i
tsiang	將	tsiang	chiang
ts'iang	鏘	ts'iang	ch'iang
tsiao	蕉	tsiau	chiao
ts'iao	俏	ts'iau	ch'iao
tsié, tsieh	借節	tsié	chieh
ts'ié, ts'ieh	且切	ts'ié	ch'ieh
tsien	賤	tsién	chien
ts'ien	千	ts'ién	ch'ien
tsin	晉	tsin	chin
ts'in	秦	ts'in	ch'in
tsing	井	tsing	ching
ts'ing	青	ts'ing	ch'ing
tsioh	雀	tsio	chio
ts'ioh	鵲	ts'io	ch'io
tsiu	酒	tsiu	chiu
ts'iu	秋	ts'iu	ch'iu
ts'iün	逡	ts'ün	ch'ün

I. Williams.		II. Hirth.	III. Wade.
tso, tsoh	左作	tso	tso
ts'o, ts'oh	錯娖	ts'o	ts'o
tsu, tsuh	祖足	tsu	tsu
ts'u, ts'uh	粗促	ts'u	ts'u
tsü	聚	tsü	chü
ts'ü	取	ts'ü	ch'ü
tsüeh	絕	tsüé	chüeh
tsüen	鐫	tsién	chien
ts'üen	全	ts'üan	ch'üan
tsui	最	tsui	tsui
ts'ui	翠	ts'ui	ts'ui
tsun	尊	tsun	tsun
ts'un	寸	ts'un	ts'un
tsung	宗	tsung	tsung
ts'ung	叢	ts'ung	ts'ung
tswan	鑽	tsuan	tsuan
tsw'an	竄	ts'uan	ts'uan
tsz'	子	tzï	tzŭ
ts'z'	此	tz'ï	tz'ŭ

I. Williams.		II. Hirth.	III. Wade.
wa, wah	瓦 挖	wa	wa
wai	外	wai	wai
wan	萬	wan	wan
wän	文	wön	wên
wang	王	wang	wang
wäng	翁	wöng	wêng
wei	為	wei	wei
wo, woh	卧 蝸	wo	wo
wu, wuh	五 物	wu	wu
ya, yah	牙 押	ya	ya
yai	崖	yai	yai
yang	羊	yang	yang
yao	要	yau	yao
yé, yeh	也 葉	yé	yeh
yen	言	yen	yen
yih	一	i	i, yi
yin	因	yin	yin
ying	英	ying	ying
yiu	有	yu	yu
yoh	約	yo	yo
yü, yuh	魚 玉	yü	yü
yueh	月	yüé	yüeh
yuen	元	yüan	yüan
yun	云	yün	yün
yung	用	yung	yung

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[Synonyms are set in *italic*.]